COMBUSTION

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BOILER PLANT OF DERBY POWER STATION, DERBY, ENGLAND

Hot Lime Soda Phosphate Treatment of Feed Water for High Pressure Boilers
By C. E. JOOS

Thermal Properties of Gases
By WM. L. DEBAUFRE

American Progress in Coal Firing of Boiler Furnaces
By H. W. BROOKS

Other Articles in This Issue By — WM. M. CARPENTER • B. J. CROSS • DAVID BROWNLIE

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VOLUME TWO • NUMBER ONE

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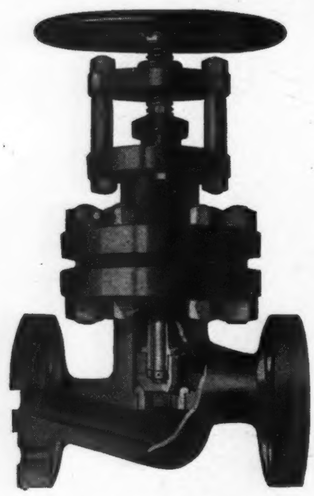

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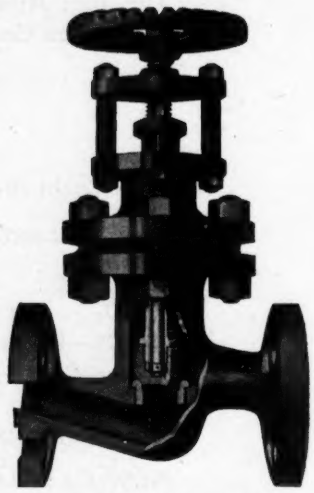

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COMBUSTION

Vol. 2 July, 1930 No. 1

Capital Investment per Unit of Electrical Output Declining

WM. M. CARPENTER

IN the electric light and power industry, revenues are lagging behind the investment required to satisfy the expanding demand for more energy and for the steady diffusion of service into new and continually leaner territory. During the past year, $5.64 of capital were required for each dollar of revenue from the consuming public, representing a "turn-over" of capital once in five and two-thirds years. Slow as it now is, this rate of turn-over is, moreover, becoming increasingly longer. Where, in 1922, it stood at once in four and three-quarter years, there is every indication that, at the end of 1930, it will have passed the figure of once every six years.

These mounting capital requirements are due to the rapidly growing expense of the facilities for transmission and distribution. It is costing more and more to bring the electricity to the consumer and the high cost of power after it leaves the plant is becoming a matter of increasing concern. Future profits of the electric light and power industry rest upon the results of a contest between increased sales and better operating efficiencies, on the one hand, and, on the other, a steadily rising investment necessary to produce the same volume of business.

The greatest offset to this high cost of distribution of power is the increased efficiency attained in generation, together with the economies which have been effected in the unit costs of power plant equipment. During the past decade, extraordinary improvements have taken place in the technique of power production. Expanding gains in the efficiency of steam plants continue with the adoption of improved methods of combustion, with higher pressures and temperatures and the steady concentration of production in ever larger stations. A rough yardstick of the operating results is the decline in the average quantity of coal required to produce a kilowatt-hour from 3.2 pounds in 1919 to 1.6 pounds thus far in 1930. During the past five years, the capital investment per unit of installed capacity has also declined. Where, during the five years between 1919 and 1924 it required an average expenditure in power plants and their equipment of $140 for each kilowatt of steam plant generating capacity in the United States, since that time this average figure has dropped to approximately $100.

Operating economies are thus being improved at the same time that capital expenditure per unit of output is being reduced. To meet the exacting demands made upon the electric light and power industry, situated as it is between the pincer's lower jaw of increasing distribution costs and the upper jaw of constantly lowered rates, still further reductions in the total cost of producing power must be attained. To obtain the best balance between the lower operating costs resulting from further savings in fuel and labor and the necessary expenditures for the requisite equipment will constitute one of the major achievements of the power plant engineers of the immediate future.

Wm. M. Carpenter

Economist
National Electric Light Association

EDITORIAL

The World Power Conference

A FEW weeks ago, the eyes of the world were trained on London where a conference of nations was being held for the purpose of limiting the power of armaments. During the past month the attention of the engineering world was focused on Berlin where the representatives of forty-seven nations were gathered to discuss developments which are contributing to the more efficient and widespread use of power in advancing the social and economic progress of all nations. What a happy commentary on the "spirit of the times" is revealed in the almost simultaneous occurrence of these two international meetings—one to restrict and curb the use of an essentially destructive power which imposes a heavy economic burden on the whole world—and the other to extend the use and benefits of a constructive power which lightens the burdens of man and contributes to his social and economic betterment.

Viewed from a distant perspective, these occasions are significant of a new and better era in which men are becoming more responsive to common needs and common opportunities, and more effective in their utilization of the technique of collaboration to serve the best interests of all.

Some of us may underestimate the basic values of this type of group effort.

The terms, conference and convention, have become a little hackneyed; they suggest the idea of verbosity of a kind that is not always conducive to practical accomplishment. Nevertheless, our rate of progress in any field of endeavor is largely dependent on our ability to take advantage of all existing knowledge and experience in that field, and any instrumentality which effects the broad dissemination of useful knowledge should be cultivated to the fullest extent.

At the Berlin Conference approximately 400 papers were presented, covering practically every phase of power—its sources, generation and utilization. Sixty-five of these papers were contributed by the American delegation. In the printed proceedings of the entire conference we shall have for permanent reference a comprehensive, authentic survey of present practice and trends in the use of power throughout the world.

That there is much for us in America to gain through better acquaintance with foreign practice and trends in the use of power admits of no argument. Economic necessity in particular localities often accelerates progress and leads to advanced practice in certain fields. Progress is not uniform throughout the world and no country, however progressive, exemplifies the most advanced methods in all phases of its industrial activity.

The Second Plenary Conference at Berlin enables American engineers to derive full benefit from the accumulated experiences of their contemporaries in other parts of the world. It confers corresponding benefits upon the engineers of all the nations participating. No greater opportunity is offered to the engineering fraternity for effectively disseminating the fruits of its work.

The Small Stoker Goes Forth to Battle

LAST year, nearly 100,000,000 tons of bituminous coal was burned in the homes, office buildings, schools and institutions of America. This is two and one-half times the annual bituminous coal consumption in our public utility plants and one-sixth of our total bituminous coal production.

It is estimated that the average efficiency at which this 100,000,000 tons of coal was burned did not exceed 50 per cent. Probably three out of every four domestic chimneys pour out objectionable smoke at some time during the day. Probably the majority of home owners have a deep rooted conviction that bituminous coal is an inefficient, dirty and bothersome domestic fuel. No wonder that fuel oil and natural gas began to cut a wide swath in the domestic fuel market.

The present fuel situation in the domestic and building field is analogous to that which formerly existed in the steam plant field where hydro-power and fuel oil challenged the supremacy of bituminous coal. This rivalry led to raising the standards of coal burning to new levels at which hydro and fuel oil could not compete, except in limited areas.

Gas and oil are now able to compete in the domestic field despite higher unit costs, only because the methods of burning coal in domestic use have been crude, inconvenient, dirty and inefficient.

The small stoker comes to the rescue.

The principles of correct coal burning are now made available to householders. At least a score of manufacturers offer reliable small stokers of correct design which operate efficiently and smokelessly and permit the use of cheaper grades of coal. 30,000 such machines are now in service and there is a potential market for 500,000 more.

Encouraged by its remarkable progress of the past few years, the small stoker is waging a vigorous battle to maintain the supremacy of coal in the domestic field. With the proper support of the coal industry, the domestic stoker may contribute much toward maintaining Coal as King.

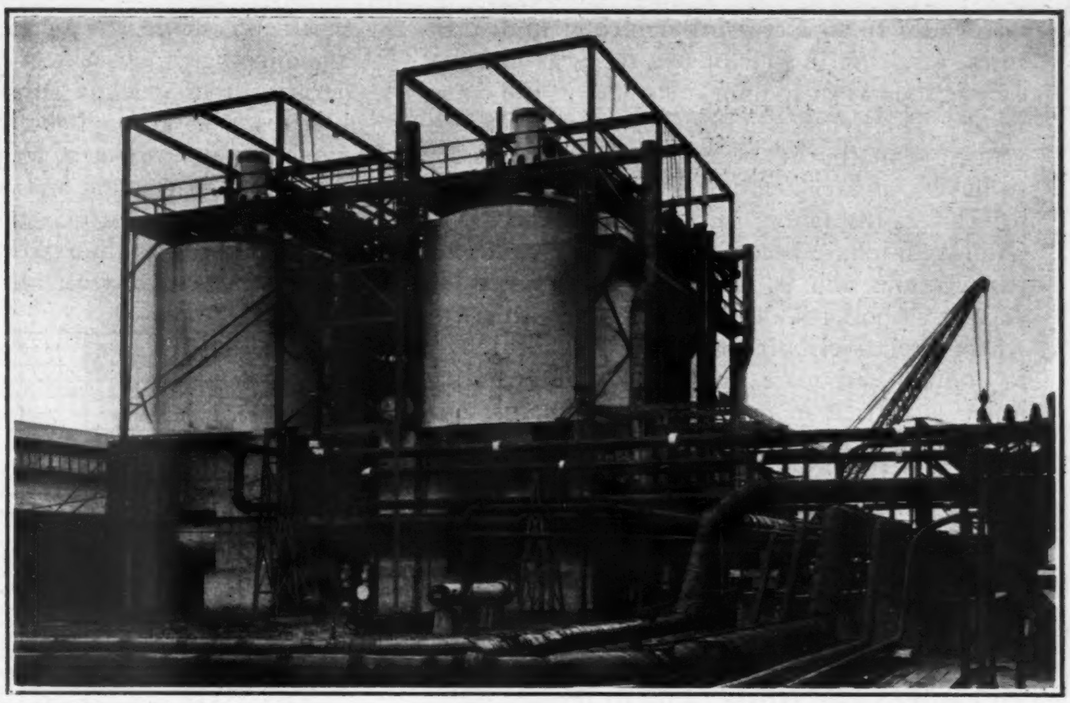

Fig. 1—Installation of largest hot process softener in the world at the plant of the Texas Gulf Sulphur Company

Hot Lime Soda Phosphate Treatment of Feed Water for High Pressure Boilers

By C. E. JOOS, Chemical Engineer, Cochrane Corporation, Philadelphia

In the various articles on feedwater treatment, published in preceding issues of COMBUSTION, there has naturally been some divergence of opinion. This is a field in which great progress has been made in recent years, but it is also one in which there is still much to be learned. The trends toward higher pressures, temperatures and capacities have introduced many new problems with respect to feedwater conditioning. These problems have led to considerable research on much of which the results are not yet available.

In presenting these articles to our readers, we have followed the policy of permitting those, whose work in this field entitles them to recognition, to express their opinions and conclusions without exercising any editorial prerogative, in the belief that this policy of free and open discussion is conducive to a better understanding of the problems involved.

IN order that high pressure boilers may be protected from even small amounts of scale or adhering deposits, the treatment of the feed water requires more care than in the case of low pressure boilers, for the following reasons:

1—At the higher temperatures corresponding to higher pressures, over-heating because of scale may so reduce the strength of the boiler metal that rupture occurs.

2—High pressure boilers cost more and are generally of larger capacity than are low pressure boilers, making it more desirable that they be held in continuous service, with no shut-downs on account of the condition of the water.

3—Boiler tubes for high pressures are more expensive because of their greater weight, so that their replacement becomes more costly and difficult.

4—The modern high pressure boiler is usually equipped with water walls or furnace tubes, which are subjected to intense heat and which frequently contain bends that tend to collect suspended sludge or particles of scale, which may interfere with free circulation.

5—Corrosion and embrittlement, even in a mild degree, are more serious than at lower pressures.

6—Foaming and priming are aggravated by the very high rates of driving and with the small drum capacities characteristic of high pressure boilers, so that particular attention must be paid to the reduction of boiler solids and alkalinity.

Several facts of physical chemistry, also indicate that the treatment of water at high pressures should be more difficult than at low pressures; namely:

1—Excess sodium carbonate in the treated water, upon which dependence is commonly placed for protecting boilers from scale at low pressures,

dissociates to an increasing degree at high pressures, resulting in four or five times as much of caustic soda as of sodium carbonate in the boiler water. The hydrate radical has no value in preventing scale, but its presence makes it necessary to have a greater amount of sodium sulphate in solution as insurance against embrittlement.

2—Calcium sulphate becomes less soluble at higher temperatures and is, therefore, more likely to deposit as boiler scale. Particularly is this true where a relatively high ratio of sodium sulphate to sodium carbonate or sodium hydrate alkalinity is carried in order to guard against embrittlement.

3—Calcium silicate scale forms more readily at higher boiler pressures and this tendency is encouraged by the common desire to hold the sodium carbonate alkalinity low in order that less sodium sulphate may be needed for the prevention of embrittlement.

For the above reasons, the lime soda treatment, which has been used satisfactorily to prepare water for low pressure boilers, should, for boiler pressures exceeding 250 pounds, be supplemented by a treatment with sodium phosphate, although with certain water supplies and certain types of boilers it may even be desirable to use a supplementary phosphate treatment at lower pressures.

The reasons for using the more expensive phosphate treatment are briefly as follows:

1—The phosphate radical is stable at all boiler pressures and remains in solution unless it can combine with the calcium or magnesium in the water.

2—The solubility of calcium phosphate is exceedingly low, which prevents calcium from concentrating in the boiler water to a degree sufficiently great to permit of its combining with either the sulphate or the silicate radicals.

3—Since the phosphate radical does not dissociate, a low hydrate alkalinity can be maintained in the boiler, which in turn permits of low sodium sulphate concentrations.

4—The presence of the phosphate radical is of itself an aid in the prevention of embrittlement as demonstrated in laboratory work by Professors Parr and Straub, as recorded in the University of Illinois Bulletin No. 177.

The goal of feed water treatment is to protect boilers from scale, corrosion and embrittlement while maintaining the lowest possible excess alkalinity, and at the same time to hold dissolved amounts of all mineral solids to the minimum, which practically is best accomplished by the hot process lime and soda treatment supplemented by an after treatment of phosphate. Where phosphate is used in the treatment of feed water, it should be preceded by a lime soda treatment, because:

1—Treatment of the carbonates of calcium and magnesium by lime costs only approximately one-tenth and one-fifth as much, respectively, as does an equivalent treatment by phosphate.

2—Treatment of calcium sulphate by sodium carbonate costs approximately one one-fourth as much as does treatment by phosphate.

3—Treatment of calcium and magnesium carbonate by lime removes both Ca and CO_3, whereas their treatment with sodium phosphate would produce sodium carbonate, which is objectionable.

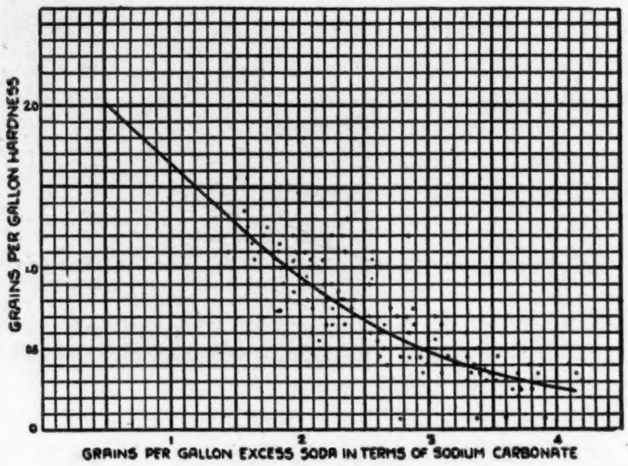

Fig. 2—Ratio of sodium carbonate to remanent hardness in softened water

It therefore follows that phosphate should not be fed to the water until the hardness has been reduced as far as possible by means of lime and soda ash, which should be followed by sedimentation and filtration to insure a removal of all of the calcium and magnesium made insoluble by the lime and soda treatment before the phosphate is added.

In considering the requirements to be met and how the hot lime and soda method meets those requirements, the following factors are to be noted:

1—Remanent hardness in the softened water.
2—Corrosiveness of the treated water.
3—Reduction in total dissolved solids and in suspended matter.
4—Protection against embrittlement of boiler metal.
5—Cost of treatment, including blow down.

One characteristic of the lime-soda hot process system, which has made it so successful in the treatment of feed water for low pressure and moderate pressure boilers is of particular advantage in the treatment of water for high pressure boilers, namely, the fact that the carbonate hardness is precipitated out of solution to the limit of solubility and without using an excess of soda ash that might cause foaming and priming and produce an unfavorable embrittlement ratio. The success of the lime and soda hot process system is largely due to the fact that it fulfills all of the above listed requirements of a treating system to a high degree. A hot process lime and soda softener properly operated will reduce the hardness to a very low degree with only a small excess of soda ash, as may be seen from the

following analyses of treated water taken in typical modern plants:

	Grains Per Gallon							
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
Calcium carbonate...	0.58	0.47	0.87	0.99	.99	0.52	0.47	0.70
Magnesium carbonate	Trace	0.17	0.17	0.52	.12	0.17	0.06	Trace
Silica..............	0.41	0.41	0.29	0.17	.52	0.64	0.47	0.23
Sodium carbonate....	2.45	2.62	2.10	1.35	1.98	1.34	1.98	1.52
Sodium sulphate.....	15.22	12.30	10.32	1.29	4.90	3.03	.47	1.87
Sodium chloride.....	1.98	1.34	.41	1.11	.35	1.81	.52	0.23
Volatile and organic.	2.33	1.11	.76	1.69	1.05	1.17	1.28	1.11
Total solids.........	23.10	18.48	15.05	7.13	9.98	8.75	5.36	5.66

The degree of hardness remaining after treatment depends upon the excess of sodium carbonate present. Roughly, for each one grain increase in excess sodium carbonate there will be a decrease in hardness of ½ grain. The hardness left in a water softened by the hot process can be reduced to zero as determined by the soap test by the addition of sufficient soda ash. This ability of the hot process to hold a low hardness is particularly valuable when supplementary phosphate treatment is to be used. Fig. 2 shows the relation between excess sodium carbonate and remanent hardness.

To protect boilers, economizers, feed lines, etc. against corrosion at elevated temperatures, deaeration is necessary, since gases such as oxygen and carbon dioxide become increasingly more active with

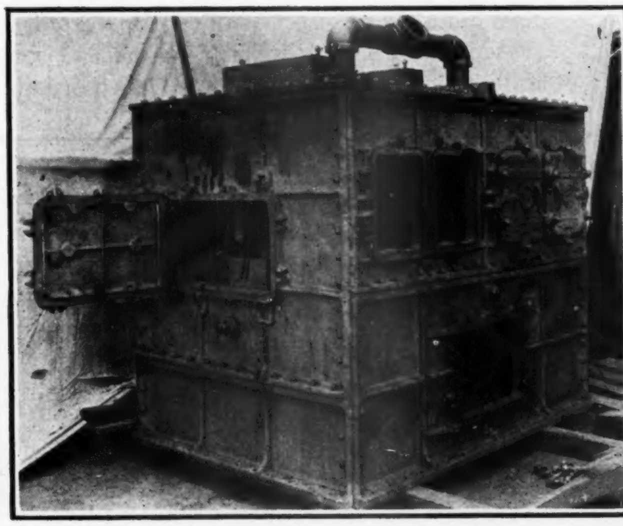

Fig. 3—Deaerating heater top for hot process softener; capacity, 130,000 lb. per hour

increasing temperature. Not only is it desirable to remove all traces of oxygen but of carbon dioxide as well, particularly in industrial plants where elaborate systems of condensate return lines must be protected.

In the hot process softener the oxygen, as well as the free carbon dioxide, is completely driven out of solution or to a low limit, according to the type of equipment used. The half-bound carbon dioxide not driven out in the heater is precipitated in the sedimentation tank by means of the lime. This complete elimination of corrosive gases gives the maximum amount of protection against corrosion. In addition to this it may be desirable to control the alkalinity of the treated water so that a predetermined pH value is maintained. This is an important consideration, since with certain feed water treatments corrosion of feed lines and economizers has taken place in spite of the fact that the water had been completely deaerated. The desired pH concentration can be maintained by simply regulating the respective charges of lime and soda.

Deaeration of the feed water can be effected by mounting a deaerating heater top on the sedimentation tank of the softener or by installing a separate deaerating heater following the softener filters, the method to be used depending on the characteristics of the raw water supply. For high carbonate waters deaeration after softening is the accepted practice, although with water reasonably low in carbonates the first method may be advantageous. Fig. 3 illustrates a 130,000 lb. per hour deaerating heater top designed to be installed as an integral part of a water softener.

The quality of the steam issuing from a boiler is dependent largely on the concentration of total solids in the boiler water. The higher the content of solids, the greater the tendency to prime and consequently the greater the necessity of increasing the blow-down. Most raw waters are of such a character that the solids are materially reduced by treatment in a hot process softener, the carbonates being precipitated without any resulting soluble byproduct. The analyses of raw and of treated water given below demonstrate this point:

	Grains Per U. S. Gallon	
	Raw	Treated
Calcium carbonate...........	7.53	0.58
Calcium sulphate............	6.48	None
Magnesium carbonate........	4.90	Trace
Silica......................	1.05	0.41
Iron oxide and alumina......	0.23	0.12
Sodium carbonate...........	None	2.45
Sodium sulphate............	10.57	15.22
Sodium chloride............	2.28	1.98
Volatile and organic........	4.20	2.33
Total solids................	37.25	23.10

The reduction in solids is 38 per cent and the hardness of the treated water by the soap test would be practically zero. The amount of suspended matter left to accumulate in the concentrated boiler water would be small and would not aggravate foaming conditions.

The A. S. M. E. recommendations concerning sulphate to carbonate ratio to be maintained to avoid embrittlement are accepted by steam boiler operators almost universally. While the cause of embrittlement may be much disputed, few engineers question the desirability of low alkalinity as a protection against failure.

With the lime and soda hot process, alkalinity can be controlled within narrow limits and usually it can be kept low enough for the desired sulphate to carbonate ratio without the addition of sulphate.

The preceding analysis of treated water indicates a ratio of 6.2, which is quite satisfactory, even though this plant operates at a pressure of 650 lb. per sq. in. As supplementary mono-sodium phosphate is fed, the ratio is further increased within the boiler. If the base exchange type of water softener had been used with this water supply, without pre-treatment with lime, the solids would have been increased by 5.4 per cent and the sodium sulphate to sodium carbonate ratio would have been reduced to 1.2, which is not sufficient at the pressure carried.

If dependence for scale prevention is placed on phosphate, which does not hydrolyze, it becomes quite possible to carry a low alkalinity. In using phosphate in conjunction with a lime and soda softener, the phosphate is fed into the already softened and filtered water, or directly into the boilers. In most cases it is not practical to feed the phosphate into the softener, since it would react with the carbonates to form sodium carbonate, thereby increasing the alkalinity, to which the same objections may be made as to softening by Zeolites. This is illustrated by the following reaction.

$$3CaCO_3 + 2Na_3PO_4 \rightarrow 3Na_2CO_3 + Ca_3(PO_4)_2$$

The action of phosphate is best confined to the boiler and should be controlled according to what is desired in the boiler. Mono-sodium phosphate is most commonly used in connection with lime soda softening, although tri-sodium and di-sodium phosphate may find application with internal treatment. The difference between the several phosphates lies in their respective alkaline producing or reducing powers. In a lime soda softener the first reaction of the phosphate is with the remanent hardness present as calcium carbonate. The reactions with the different forms of phosphate are as follows:

$$3CaCO_3 + \underset{\text{(Tri-sodium)}}{2Na_3PO_4} \rightarrow Ca_3(PO_4)_2 + 3Na_2CO_3$$

$$3CaCO_3 + \underset{\text{(Di-sodium)}}{2Na_2HPO_4} \rightarrow Ca_3(PO_4)_2 + 2Na_2CO_3 + H_2O + CO_2$$

$$3CaCO_3 + \underset{\text{(Mono-sodium)}}{2NaH_2PO_4} \rightarrow Ca_3(PO_4)_2 + Na_2CO_3 + 2CO_2 + 2H_2O$$

$$3CaCO_3 + \underset{\text{(Phosphoric acid)}}{2H_3PO_4} \rightarrow Ca_3(PO_4)_2 + 3H_2O + 3CO_2$$

The tricalcic phosphate $(Ca_3PO_4)_2$ would only form in this equation if sufficient (OH) radical were present.

The CO_2 indicated as a by-product is absorbed by the excess alkali introduced into the softener. It will be noted that the by-product of sodium carbonate formed is proportional to the sodium content of the phosphates. Thus the tri-sodium phosphate produces three times as much by-product sodium carbonate as does the mono-sodium phosphate.

Phosphoric acid offers the lowest alkalinity with the hot process system, but since the handling of acid introduces a difficulty, mono-sodium phosphate has become the most popular. Its value lies in the fact that if added after the hardness has been precipitated, it has alkaline reducing properties, according to the formula:

$$Na_2CO_3 + NaH_2PO_4 \rightarrow Na_3PO_4 + H_2O + CO_2$$

From this equation it is evident that one molecule of mono-sodium phosphate breaks up one molecule of sodium carbonate to form one molecule of tri-sodium phosphate, which is desirable in the boiler water and does not break down.

The mono-sodium salt is slightly acid, but there is now on the market a molecularly dehydrated mono-sodium phosphate which is neutral, but at the same time within the boiler retains the alkaline reducing properties of mono-sodium phosphate.

The use of mono-sodium phosphate in conjunction with the lime-soda process makes an ideal combination, since it produces a low hardness and low alkalinity water for the boilers.

Different methods of feeding phosphate are followed. It may be fed to the softened water beyond the softener filters, as illustrated in Fig. 4, or it may be pumped directly to the boilers. The latter method has the advantage that it eliminates any trouble due to feed line deposits, which may occur through the precipitation of remanent calcium carbonate hardness, although it is claimed for the molecularly dehydrated mono-sodium phosphate that feed line deposits do not occur.

The new phosphate proportioner illustrated in Fig. 5 is used in conjunction with a lime and soda system and proportions the phosphate in accordance with the amount of raw water used. Tank "A" contains the lime and soda and tank "B" the phosphate. The lime and soda proportioner, not shown, delivers lime and soda ash to the softener in accordance with the flow of raw water. The level of solution in tank "B" is made to follow that in tank "A" by means of the displacement balance arrangement. This consists of two displacement bodies "D" and "E," both heavier than the solutions in which they are submerged, hung at the ends of a beam supported in the middle on the ball bearing "F." Motion of the beam operates to open or close the valve "G," depending upon the relative positions of the displacement members "D" and

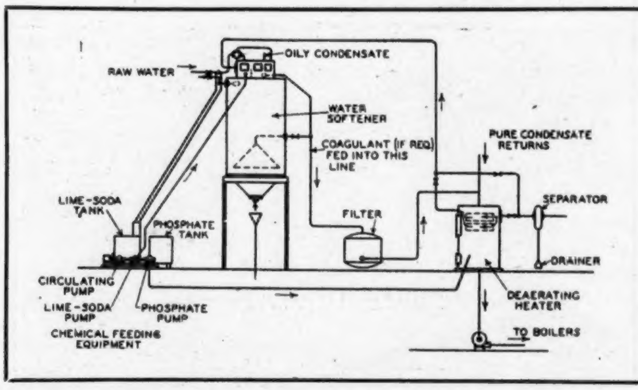

Fig. 4—Method of feeding phosphate into deaerating heater

"E." For purpose of illustration, let us suppose that the level in the tank "A" is lower than the level in tank "B." This then means that the buoyant body "E" will lose weight and create a counterclockwise moment tending to open valve "G." This will continue until the level in "B" has fallen to the same level as "A" when the valve will close.

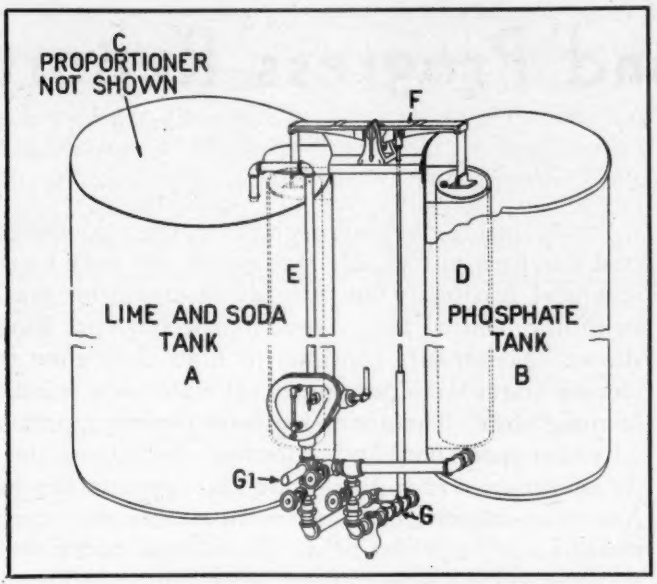

Fig. 5—Phosphate proportioner

Suppose that the valve in tank "B" is lower than the level in tank "A." In this case the weight "D," having less displacement than "E," will set up a clockwise moment, closing the valve "G" until the level in the two tanks is equal. The proportioning of the phosphate to the lime and soda, and hence to the raw water, in actual practice is practically continuous. The phosphate thus measured out is diluted with water and pumped either directly to the boilers or into the feed line, hot well, or other suitable points, depending upon plant arrangements.

The results in practice from the combination lime-soda and phosphate treatment have been most encouraging, and all of the advantages expected from a theoretical view-point have been realized. High pressure plants using this combination have operated for a sufficient length of time to justify the conviction that feed water can be treated satisfactorily by this method, regardless of the pressure or the amount of make-up water used. One plant, which has been in operation for over a year at 650 lb. has maintained its boiler tubes clean to the metal, even though at times the make-up approached 100 per cent. Other plants operating at 450 lb. with 100 per cent make-up have shown similar results. This performance, although even small quantities of deposit may cause ruptured tubes, meets the demands of present high pressure boiler practice. As showing the effect of even a small amount of scale, Partridge and White in an article, "Thermal Effects of Boiler Scale", which appeared in the September, 1929, issue of *Industrial and Engineering Chemistry*, conclude that boiler tubes of ordinary low carbon steel, capable of safely withstanding continuously a maximum temperature not exceeding 480 deg. cent. (900 deg. fahr.) with boilers at 600 lb. gage pressure, will not tolerate on the exposed tubes calcium silicate scale thicker than 1.1 mm. or 0.043 inch.

The following analyses of boiler water in high pressure steam plants indicate that the desirable low alkalinity combined with a proper sulphate-carbonate ratio can be realized.

Boiler Pressure lb.	350	450	650
	Grains Per U. S. Gallon		
Calcium phosphate	Trace	Trace	Trace
Silica	0.47	5.65	2.10
Magnesium hydrate	Trace	Trace	Trace
Iron oxide and alumina	.....	......	......
Sodium carbonate	4.02	4.96	3.09
Sodium sulphate	61.10	110.52	106.10
Sodium chloride	7.64	3.67	14.58
Sodium hydrate	8.17	4.66	7.58
Tri-Sodium phosphate	3.15	13.41	6.70
Volatile and organic	13.52	18.60	7.92
Total solids by evap	98.06	170.47	148.08

With certain water supplies, difficulty has arisen from the formation of silicate scale, even at moderate pressures. Silicate scale is perhaps the most difficult to overcome, but the supplementary phosphate treatment has proved to be a most happy solution of the problem. Fig. 1 is a photograph of the largest hot process softener in the world, as partially completed, having a total capacity of 420,000 gal. per hr. At this plant, phosphate is pumped directly to the boilers for the prevention of silicate scale.

In southern California, and in certain parts of Illinois, Texas, and New Jersey, well waters frequently have a high content of natural sodium carbonate and of temporary hardness, low sulphate hardness and relatively high silica. Such a water, as typified by the following anaylsis, is apt to form a hard silicious scale, produce a high concentration of alkali in the boiler and to lead to embrittlement.

	Grains Per U. S. Gallon
Calcium carbonate	3.91
Magnesium carbonate	1.40
Silica	1.11
Iron oxide and alumina	0.12
Sodium carbonate	5.72
Sodium sulphate	0.23
Sodium chloride	3.32
Volatile and organic	2.16
Total solids by evap	17.97

With the hot process softener such a water can be treated by lime and gypsum with supplementary phosphate to produce a feed water meeting the most rigid requirements. The lime precipitates the carbonate hardness, while the gypsum reduces the sodium carbonate content, at the same time so increasing the sodium sulphate as to provide a proper sulphate to carbonate ratio. The supplementary

(*Continued on page 50*)

American Progress
in Coal Firing of Boiler Furnaces

A Review and Progress Report

By H. W. BROOKS
Consulting Engineer,
NEW YORK

Abstract of a symposium of six papers presented at the Second Plenary Meeting of the World Power Conference, Berlin, Germany, June 16 to 25, 1930.

THE idea of a World Power Conference came to fruition during the Wembley Exhibition in 1924 when the First Plenary Conference was held in London. Since that time there have been four sectional conferences. In the Second Plenary Conference held in Berlin during the past month, leaders in the various fields of power, representing forty-seven nations, presented papers and participated in the discussions. Among the papers of particular interest to COMBUSTION'S readers is the symposium reviewed in this article, which was prepared by H. W. Brooks, in collaboration with executives of five of the principal manufacturers of coal burning equipment.

¶ In the introductory section of this symposium, Mr. Brooks analyzes the situation with respect to the use of stokers and pulverized fuel as follows:

"Engineers of other nations, familiar with American pulverized fuel literature of the past twelve years, will no doubt be astonished at the relatively small proportion of the total American boiler fuel so fired. Rapid as have been the advances made in pulverized coal technology in the United States, the new method has today by no means swept the field. A fair estimate of the annual tonnage of total coal burned under American boilers will approximate as follows:

Hand Firing	275,000,000	tons
Underfeed Stokers	100,000,000	"
Chain Grate Stokers	40,000,000	"
Pulverized Coal	25,000,000	"
TOTAL	440,000,000	"

"Even during the past seven years, since powdered coal has been universally recognized not only as to technical feasibility but also as to operating practicability, United States government statistics have shown that stokers continue to hold their own in serving about sixty per cent of all water tube boilers manufactured. There is no reason at present apparent why this ratio should not continue. Increasing clarity of perspective is furthering the appreciation by American engineers and plant operators that each method has its proper field of usefulness, hence that it behooves us as engineers to establish accurate lines of economic demarcation between the respective fields rather than to regard any one method as the ultimate panacea for all evils of the boiler room.

"It is, therefore, encouraging to note that the same American manufacturers responsible for the majority of the powdered fuel equipment manufactured are also numbered among the nation's largest stoker producers—an economic trend undoubtedly destined to continue. Still another helpful trend is the tendency toward merging of firing equipment, water-cooled furnace and boiler manufacture into single corporations capable of an undivided responsibility for the overall results of the complete steam generating unit."

To the trends mentioned the author attributes the astonishing progress of the past decade which has witnessed the increase of maximum capacities of single boilers from 150,000 lb. of steam per hour to 800,000* lb. per hour, with consequent decrease in investment costs and increased efficiency; the increase in pressures from 300 to 400 lb. per sq. in. to above 1800 lb.; the increase of heat absorption rates per sq. ft. of heating surface from 10,000 to more than 25,000 B.t.u.; and the decrease in the best central station operating practice from about 42,000 B.t.u. per developed horsepower hour (33,479 B.t.u.) to about 38,000 B.t.u.

Discussing the progress that has been made in eliminating hand-firing in favor of stokers, the author states:

***(Ed. Note: Since this paper was prepared, a capacity of 1,270,000 lb. of steam per hour has been obtained from one of the new units at the East River Station of the New York Edison Company.)**

"Both powdered coal and stoker equipment manufacturers have concentrated on that vast field of inefficiency represented by the hand-fired plant. What powdered fuel has gained at the expense of stokers in the larger and most modern plants, stokers have more than regained in the conversion of hand-fired plants—an economic anomaly in a nation of high labor rates. At the present rate of conversion, with the possible exception of railway locomotive hand-firing, few if any such installations will remain within the coming decade. The City of Chicago has, in fact, recently abolished by law new installations of hand-firing of all boiler furnaces exceeding an output of 300,000 B.t.u. per hour. The growth of the small stoker serving boilers of less than 2,000 sq. ft. of heating surface has been especially noteworthy—more than 30,000 bituminous stokers being already in service in a substantially new branch of the industry scarcely six years old."

Another development of great importance has been the increased availability and dependableness of fuel burning equipment. In this connection the author points out that availability records of 90 to 93 per cent are being secured for complete steam generating units, a condition which has materially decreased the fixed charges on reserve equipment.

The trends with respect to pulverized fuel equipment are summarized as follows:

"1. The growing popularity of unit pulverizers even on applications of largest fuel requirements.

"2. Increasing realization of the essentialness of fine grinding for best results.

"3. Decreasing equipment and installation costs per unit output and consequent reduction of fixed charges.

"4. Horizontal turbulent burners almost universally recommended for bituminous coal.

"5. Development of cheaper and more efficient methods of separation of ash from chimney gases.

"6. Water-cooled walls rapidly becoming standard in boiler practice even in the medium sizes.

"7. Air preheated by waste heat (sometimes as high as 600 deg. fahr.) for drying raw coal in feeders and pulverizers and for increasing temperatures within the furnace is generally being specified.

"8. Automatic controls are becoming less costly and more dependable.

"9. Slagging type furnaces for low fusion ash coals are attaining rapid popularity—two additional installations following the pioneer at Buffalo—still another at Toronto, Ohio, and the latest now under contract for Hell Gate Station, New York, for serving the largest boiler ever fired with unit mills.

"10. Portable truck mounting of pulverizers has been employed with success to reduce initial costs where operating cycles permit."

Among the noteworthy trends evident in the stoker field, the following are mentioned:

"1. Increase in stoker sizes to projected areas exceeding 700 sq. ft. on underfeed and 684 sq. ft. on chain grates.

"2. Increase in burning rates per square foot of burning area per hour to as high as 70 to 75 pounds on underfeeds and 60 pounds on chain grates; also increases of chain grate speeds to 60 feet per hour with bituminous and to 100 feet per hour with anthracite.

"3. Increases of stoker length to more than 20 feet.

"4. The use of preheated combustion air up to from 300 to 350 deg. fahr., depending on the coal.

"5. The rapidly growing use of water-cooled walls and arches.

"6. The better co-ordination and proportioning of stoker, boiler, economizer and preheater with respect to each other.

"7. Bettered zone control both for coal and air distribution.

"8. The increasing use of clinker grinders with larger and deeper clinker pits, particularly on the larger stokers.

"9. Increasing use of both rear and front end mixing arches to secure more complete burning out of the combustion gases.

"10. Wider realization of the economic usefulness under American conditions of the small and domestic stoker."

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¶ The second paper in the symposium by E. G. Bailey, President of the Fuller Lehigh Company, points out that there are three factors which are to be considered in the economic solution of steam generating problems, namely: thermal efficiency, investment cost of plant, and availability for use. With respect to these factors, the author states that a real advance has been made in thermal efficiency, not only from a purely technical standpoint, but also from an economic one; that plant investment costs per unit of output have decreased with the marked increase in boiler sizes; and, that the increased investment represented by the large units has necessarily improved the factor of availability for use.

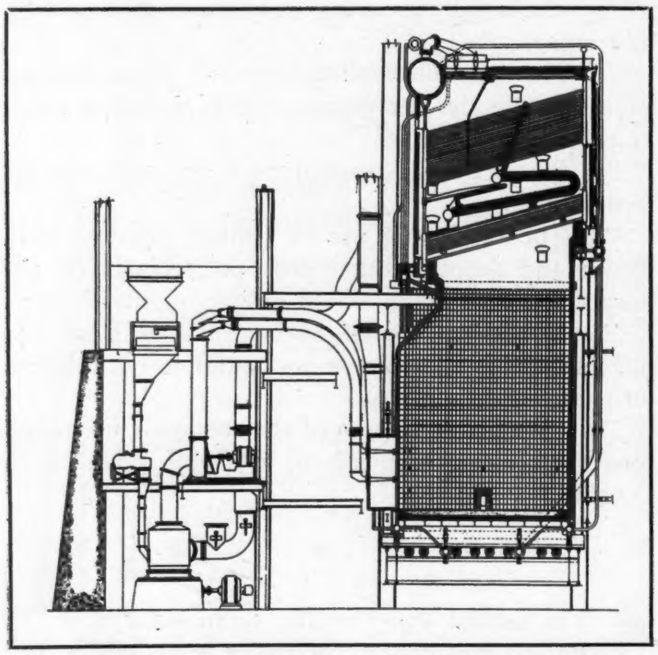
Commenting on the rapid development in pulverized coal firing, the author states that this method has established itself as the most reliable for high capacity units. Emphasis is placed on the flexibility of pulverized coal firing, permitting the efficient use of widely varying grades of coal in single installations, and on the part played by the development of water-cooled furnace walls in removing capacity limitations.

The water-cooled furnace development has also contributed to the more extensive use of air preheaters due to its removal of limitations of furnace temperatures, and highly preheated air in turn has been an important factor in the more general adoption of pulverized coal firing and water-cooled walls.

In discussing the unit or direct-fired method of burning pulverized coal, the author states:

"Continued development and experience have eliminated the original objections to the direct-fired system based upon lack of reliability, lack of continuity of operation and lack of adaptability to control."

Commenting on the importance of furnace design and construction in the development of high capacity units, reference is made to the slag type furnace as being quite widely applied in pulverized coal firing.



Pulverized fuel fired unit equipped with slagging type furnace

In this type of furnace the ash accumulates on the floor in liquid form and is tapped out intermittently, and a larger percentage of the ash is collected in this manner than if it were removed in a dry and dusty condition. Other advantages mentioned in favor of this type of furnace are, that it is a cleaner and simpler method of ash removal, requiring a minimum of labor and expense; that it decreases building costs due to reduction in headroom; eliminates expense of ash handling equipment; permits more effective use of furnace volume; and eliminates practically all air leakage into the furnace. In commenting further on the increasing use of water-cooled walls, the author analyzes certain conditions affecting their operation and reaches conclusions which favor the idea of using a protective covering over the water wall surface. This analysis and the author's conclusion are quoted as follows:

"With the present day tendency toward higher capacity units, the possible failure of water wall tubes assumes an increasing importance. In the design and operation of equipment, ample consideration should be given to the factors tending to produce tube failures. It is recognized that water wall tubes are subjected not only to internal pressure but to temperature induced stresses resulting from a temperature difference, or gradient through the metal of the tube wall. The magnitude of these induced stresses, however, is as yet a more or less uncertain factor. Experience and observations seem to indicate with water-cooled furnace walls operating at 1400 lb. pressure and at any reasonable rate of combustion per cu. ft. of furnace volume, that even a small amount of scale in the tube, the least interruption in circulation, or any direct flame impingement is likely to cause the safe working stress of the tubes to be exceeded because of the physical limitations of steel tubes at elevated temperatures and high pressures.

"Furnace wall tubes are undoubtedly subjected to more severe conditions than the boiler or superheater tubes. Due to their location they are at times subjected to higher rates of heat input per sq. ft. of exposed tube surface than any other part of the boiler unit. This is especially so because of the possibility of flame impingement. Furthermore, these tubes are usually vertical. Thus the steam film formed when heat is applied to water at saturation temperature persists in following up the hot side of the tubes, thereby creating a heat insulating zone of appreciable magnitude. Whenever incrusting impurities are present in the water, scale forms most rapidly on the surfaces where the higher rates of absorption are taking place.

"All of these factors tend toward increasing the temperature of the furnace wall tubes locally. For these reasons it is important to protect the furnace wall tubes against excessively high rates of heat transfer and to distribute the heat to various portions of the tube without high localized intensity by a coating of slag or other suitable means. This can be accomplished and the strength of the tube effectively supplemented by armouring it with a block structure which will minimize the danger from these sources."

Discussing the problem of slagging of boiler tubes, the author states:

"This difficulty, usually more pronounced as the fusing temperature of the ash becomes lower, can be reduced if not entirely eliminated by proper spacing of boiler tubes and correct baffling so that the entering gas velocity is within reasonable limits. The proper location of high heat absorbing water wall surface is helpful in minimizing this difficulty. The size of coal particles also has an important effect, for with two particles of the same fusing temperature, the larger will remain sticky while the smaller particle will radiate enough heat to the boiler tubes as it approaches, to be cooled below the sticky point by the time it strikes the tubes."

This paper is concluded with a reference to turbulent burning, an intimate mixture of the fuel and all of the combustion air immediately upon entering

the furnace in such a manner that complete combustion is obtained with the minimum of time, space and excess air. The author points out that furnace and burner design both play an important role in the accomplishment of the results of turbulent burning, and that the obtaining of a high degree of turbulence has a marked effect on the capacities obtainable from steam generating units.

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The third paper in the symposium is by W. L. Martwick, Manager, Pulverizer and Furnace Division, Foster-Wheeler Corporation. This paper discusses the use of pulverized coal in industrial plants. Following a consideration of the generally recognized advantages of this method of combustion, the author discusses the relative merits of the unit and storage system as follows:

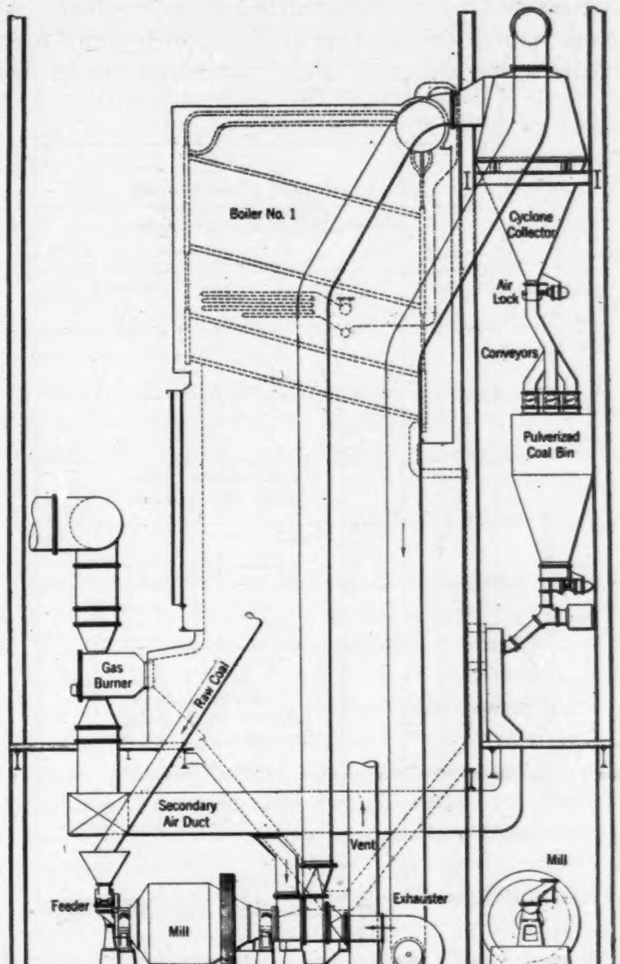
"The Unit System is less complicated than the Storage System since it consists simply of a mill from which the coal is discharged directly to the burners. Seldom, if ever, is it necessary to install separate dryers, as the grinding and transport of the coal are the only factors which make it advisable to remove moisture. Unit mills usually employ air drying within the mill from which the drying air passes directly to the furnace where it is used to burn the coal.

"One may inquire what reasons may justify the use of a more complicated storage system. Perhaps the most important reason lies in the ability to operate the mills with the storage system at their most economical loading, which corresponds with the maximum capacity. It is possible to install smaller mills with this system and to use less power for grinding of the coal. In some cases it is feasible with the storage system to install mills sufficiently large to permit all the pulverizing to be done when the power output of the plant is low, and the arrangement thus tends to reduce the required capacity from the boilers. Until recently the storage system provided a more positive distribution of fuel to a number of burners in the furnace. In recent years, however, more has been learned about dividing a stream of coal from the unit mill so that this advantage is much less important than it was formerly."

This comparison is concluded by the following opinion:

"In view of the excellent results obtained with the unit system, American engineering opinion is rapidly trending toward the belief that greater simplicity and lower cost recommends its use in the average industrial plant."

The author then proceeds to describe the various types of pulverizing mills used with the unit system, outlining the characteristics and conditions of operation to which each type is best suited. He recommends that the "beater" type mill, also referred to as the hammer or impact type, be used in small installations except when the coal is unusually abrasive. For larger installations this type, as well as the roller and ball mill types, should be considered and the selection made on the basis of the particular conditions to be met.



Storage System layout arranged for use of blast furnace gas and pulverized coal

Then follows a consideration of the various types of furnaces, solid refractory, air-cooled refractory, and water-cooled, their respective B.t.u. liberations, and the types of burners adapted to each. The various types of burners are then classified and described.

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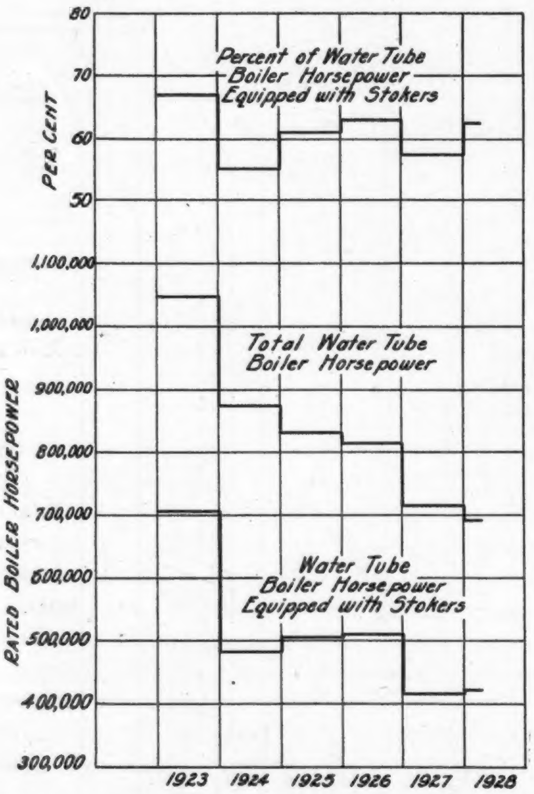
The fourth paper, by F. H. Daniels, President of the Riley Stoker Corporation, relates to Underfeed Stokers. The author states that in America today boilers totalling nine million rated boiler horsepower are equipped with underfeed stokers, and that government statistics indicate that stokers are holding their own despite the growing popularity of pulverized coal. Frequently stokers have been chosen in preference to pulverized coal firing in the eastern part of the United States where high grade bituminous coal is the fuel to be used, but in the

midwestern states, where the coals are higher in ash and moisture and of lower fusion temperature ash, the use of underfeed stokers is debatable.

In discussing the increase in size of stokers brought about by the development of larger boiler units, the author states:

"Mechanical stokers have been increased rapidly in size and particularly in the length. In the multiple retort type, stokers are now built to fill up the entire space available under the boiler, and lengths



Annual sales of stokers and water tube boilers, showing percentage of stoker-equipped boilers

over twenty feet are not uncommon. This big increase in size has necessitated many changes and refinements in stoker design.

"A few years ago, a steam output of 100,000 to 150,000 pounds of steam per hour was considered a big output. Today the size of underfeed stokers has increased so that a production of 400,000 to 500,000 is entirely feasible and economical. To obtain such steam outputs and the corresponding coal burning capacity of the stokers, it has become necessary to build stokers having projected areas of over 700 sq. ft. In the multiple retort field there are being built or have been built, single ended stokers having a projected grate area of 713 sq. ft. and double ended stokers having a projected grate area of 718 sq. ft.

"The increase in coal burning capacity per stoker fired furnace and the total heat release per furnace have practically quadrupled during the past thirteen years. The heat release per square foot of grate surface has increased much less rapidly, however, indicating that the heat release per furnace has been due in great part to the increase in the size of the stokers. It is hard to obtain exact figures showing the increase in coal burning capacity per square foot of grate surface though there is no doubt of such an increase taking place. Stoker installations are being operated today at continuous overloads which a few years ago represented the short peak capacities. While there are records of old installations showing operation at 70 to 75 lb. of coal per square foot of stoker area per hour, these cases seemed to be the exception whereas today such coal burning rates are not uncommon. Water cooling of furnace walls has made this higher heat release possible by preventing much of the clinker and slag difficulties and by giving a furnace lining which would stand up under this high heat release."

Commenting on the improvement in efficiency resulting from the use of preheated air, the author points out that there is still much discussion as to the permissible temperature of preheated air to be used with stoker firing. He goes on to say that most authorities agree that the economical limit at present is between 300 and 350 deg. fahr. and that, while it is possible to operate with higher temperatures, much more dependable and satisfactory results are obtained by operating within this limit. It is further pointed out that the use of highly preheated air sometimes causes radical changes in the way the fuel acts on a stoker.

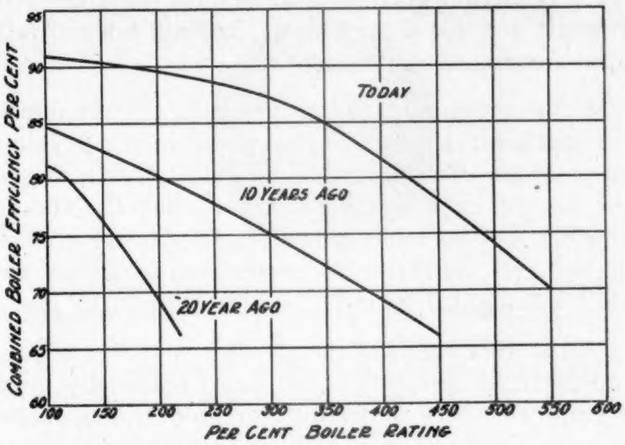
During the past ten years, there have been many improvements and refinements in underfeed stoker design. These are discussed as follows:

"The increased length of the underfeed retort brought about improved methods of feeding and distributing the fuel. This brought about the development of different mechanisms for controlling the distribution of the coal along the stoker and its travel through the various zones to the ash pit. This problem has been approached by the different stoker manufacturers in different ways. Today stokers are underfeeding coal 18 to 20 feet as compared with 6 to 7 feet ten years ago. To discharge the large quantities of ash which resulted from the use of such long stokers, clinker grinders with large and deep clinker pits are almost entirely used on all stokers fifteen feet long or over.

"The use of preheated air also demanded changes in the design of stokers. It is apparent that some means had to be developed for taking care of expansion and contraction of those parts of the stoker subjected to the preheated air. It also demanded changes in the tuyere construction. Equally important as the effective control of fuel throughout the the stoker is the effective control of the air supply. Most of the stoker manufacturers have recognized this and new methods of controlling the air to the different zones of the stoker have been developed."

The concluding paragraph of Mr. Daniels' paper offers the following summary of developments which have maintained the popularity of the underfeed stoker as a major means of firing steam boilers:

"In the past ten years, stokers have more than doubled in projected grate areas, and in coal burning rates per square foot of grate surface. When furnace design is proper and when preheated air used, the efficiency of the steam generating unit has increased approximately 10 per cent. Preheated air is used up to 350 degrees. Clinker grinders are practically standard on sizes fifteen feet or over; control of fuel and air has been greatly improved."



Comparison of past and present-day stoker-fired boiler performance

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The fifth paper by H. D. Savage, President of Combustion Engineering Corporation,* pertains to the traveling grate stoker. In the introductory paragraphs it is stated that the terms "traveling grate stoker" or "chain grate stoker" are applied more or less indiscriminately to those stokers in which the grate consists of an endless belt of grate members suitably mounted on shafts at front and rear. There is, however, a difference, in that in one type (the chain grate) the chain itself is the fuel bearing surface, and in the other (the traveling grate) the driving chains are below the grate proper and merely serve to carry the fuel bearing surface.

The original chain grate stoker was invented by Jukes in England in 1841, and the first traveling grate stoker was brought out by Walker in America in 1871. While the chain grate type was used extensively in the latter half of the nineteenth century, it was not until 1895 that the traveling grate stoker, came into use.

The author reviews the early history and development of both types of stokers, pointing out that the chain grate type was used mainly for free burning bituminous coal of high ash content and that the earlier installations were all similar, using low settings with relatively long front arches.

*Mr. Savage resigned this office as of February 17, 1930.

In 1895, Eckley B. Coxe developed a forced draft traveling grate stoker for burning small sizes of anthracite coal, a fuel not previously burned with success on any stoker. The use of this stoker was later extended to include coke breeze and non-coking bituminous coals.

With the adoption of increased setting heights, larger furnaces and zoned air control, combustion results were greatly improved and the capacity range extended. The successful use of forced draft and zoned air control with the traveling grate stoker led to their adoption in connection with chain grate stokers which previously had used natural draft only. This development greatly broadened the field of the chain grate stoker and today it is considered as unequalled for American free burning coals of the middlewest, lignites and sub-bituminous coals. It has also been successfully used for burning anthracite coal and coke breeze.

In the concluding paragraphs, the author discusses the developments of recent years in connection with traveling and chain grate stokers with respect to stoker sizes, furnace design and field of application, as follows:

"Stokers of this type are in successful use in sizes up to 24 ft. by 22 ft., or 528 sq. ft. The rapid advance of the forced draft grate stimulated the manufacturers of the older natural draft grates and, in consequence, furnace designs were improved, arches raised and the relations of arch length, height and position in reference to cold boiler surface studied. The performance of this type has been thereby greatly improved though it is and will remain subject to its inherent limitations imposed by natural draft.

"In connection with the forced draft chain or traveling grate, experiments were made with arches placed over the rear end of the stoker and extending forward to within a few feet of the front end, and for certain fuels have resulted in a material increase in capacity. Double arches, that is both front and rear arches, have also been proven of advantage, particularly where a variety of coal must be burned. A problem of increasing importance, the rapid destruction of the brickwork due to the higher combustion rates, has been solved by the use of partly or wholly water-cooled arches and side walls.

"Today, it may be said that in its two types, the traveling grate and the chain grate, either with or without forced draft, this stoker will satisfactorily fulfill a wide range of applications from the low capacity, low cost installations for burning a very cheap coal, to a modern up-to-date and highly efficient central station in free burning coal districts. This stoker is self-cleaning, requires little power to drive and low forced draft pressure. The maintenance cost compares favorably with any other type of stoker. With forced draft, when burning low grade, high ash, free burning bituminous coals or anthracite, coke breeze, lignite and sub-bitumi-

nous, the chain or traveling grate stoker has no equal."

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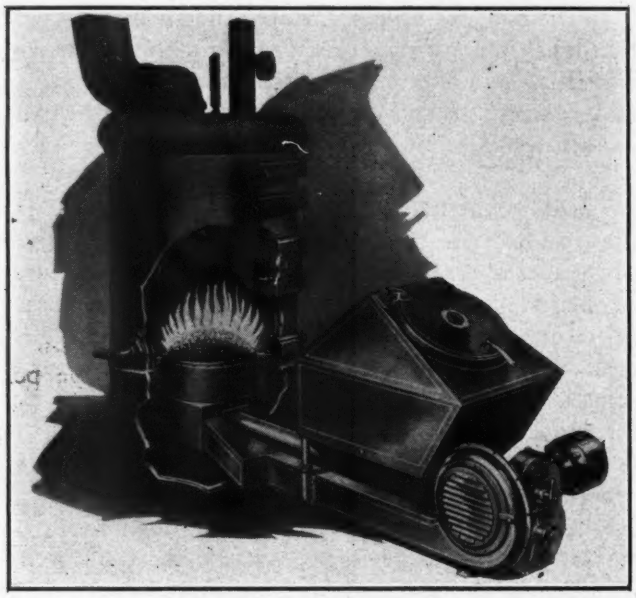
The sixth and concluding paper of the symposium is on the subject of small and domestic stokers for boilers below 200 hp. and is contributed by T. H. Banfield, President of the Iron Fireman Manufacturing Company. After briefly reviewing the tremendous mechanical advancement of this age, the author says:

"In the face of this economic demand, it was inevitable that the mechanical coal stoker should eventually become practicable for use in the hundreds of thousands of smaller boilers in industry, commercial buildings, institutions and homes. It is, in fact surprising that this had not taken place until after nearly a half century of successful application



Typical small stoker installation under domestic boiler

of stokers serving large power boilers. Until but a few years ago, it was generally believed that boilers of less than 200 hp. could not be equipped economically with mechanical stokers. Possible economies and efficiency increases were considered insufficient to warrant the investment.

"Increasing pressure of economic demand, however, has within the last decade forced exhaustive research and experiment in an effort to design a stoker within reach of the average small boiler operator and at the same time to provide economies and benefits even additional to those already possible with large stokers.

"In June, 1924, the first of these small automatic coal stoking devices was introduced to the American market. This pioneer effort consisted of an automatically operated and controlled self-contained unit of the underfeed principle, conveying the coal from a hopper into a single retort by means of a motor driven spiral worm. Though leaving much to be desired by way of mechanical refinements, this machine embodied sufficient of the essential requirements peculiar to the field of smaller boilers to gain immediate acceptance and subsequent technical refinements based on the growing experience of the past six years today leave little to be desired in mechanical performance. Today the small underfeed stoker generally uses the combination of a compact speed reduction gear for coal feeding together with a small fan for forced draft feeding, both driven from a common electric motor."

While recognizing the achievement of overcoming the mechanical difficulties involved in the development of an efficient and economical small stoker, the author expresses the opinion that the success attained can be attributed more to sound merchandizing and standardized production than to any basic mechanical innovation. He goes on to say:

"Manufacturers have been content to provide a standardized unit performing with reasonably high average efficiency under differing conditions, rather than to seek optimum technical results in each individual case. Even in such manner average performance showed savings ranging from 15 per cent to 50 per cent of former costs with hand firing Such substantial economies more than satisfied the buyers, installation was simplified, and production of a standardized unit made possible."

The necessity of providing sales, installation and service facilities within a first cost that would not be regarded as excessive by the average small stoker prospect represented a tremendous problem. In this connection, the author states:

"The task was eventually accomplished by employing a corps of specially trained sales executives and graduate engineers whose sole duty it was to counsel the dealers and their salesmen on sales and engineering problems. As the number of dealers and salesmen increased, this teaching force was doubled, trebled and quadrupled until today a specially trained counsellor is employed for each twenty dealers. In short, an itinerant institute of combustion engineering has been developed.

"With the advent of domestic stokers, the service problem loomed into huge proportions. Not that the home units were inherently less efficient than the larger sizes, but owners in practically all cases were totally uninformed regarding their operation and adjustment and would, at the first sign of irregularity, call the dealer for service. Again manufacturers perceived the need of education and promptly set about to teach the owners, through their dealers, how to operate their machines. This has been a slow and costly process, but good progress has been made. Today every dealer thoroughly instructs the new owner in proper operation and adjustment when making the installation. This has

(*Continued on page 55*)

The Thermal Properties of Gases*

By WM. L. DE BAUFRE
International Combustion
Engineering Corporation
New York

So much favorable comment has been received on the series of articles by Mr. De Baufre, of which this is the sixth, that we are presenting this brief biographical sketch in order that our readers may be better acquainted with the author.

Mr. De Baufre was graduated from the Baltimore Polytechnic Institute in 1903, and subsequently acquired the degrees of E.E., M.E. and M.S. from Lehigh University. He taught at Baltimore "Poly" for several years and during the latter part of this period was Head of the Department of Engineering there. For a number of years thereafter he was Mechanical Engineer with the U. S. Naval Engineering Experiment Station, leaving this work to become Professor of Mechanical Engineering and later Chairman of the Mechanical Engineering Department at the University of Nebraska. He left this position in 1926 to become head of the Technical Research Department of International Combustion Engineering Corporation, which position he still holds.

Mr. De Baufre has published numerous papers on the theory and performance of the mechanical equipment of power plants. He has also been identified with the production of helium by the U. S. Government, having been Consulting Engineer from 1921 to 1926 for the Bureau of Mines as a member of the Board of Helium Engineers. Mr. De Baufre is regarded as one of the country's leading authorities in the field of thermodynamics.

ANY fluid may be made to assume either the liquid or the gaseous state simply by variations in temperature and pressure; and only when the thermal properties of the liquid and of the saturated and superheated vapor of the fluid are known and tabulated (or given graphically) for various temperatures and pressures, can accurate thermodynamic calculations be made under all conditions as explained in previous articles for water and steam. The thermal properties have been determined with a fairly high degree of accuracy and tabulated for a number of fluids, such as ammonia, carbon dioxide, sulphur dioxide, etc., used in refrigeration and other industrial processes where alternate liquefaction and vaporization occur. However, when a fluid remains in the gaseous state in an industrial process, a complete tabulation of its thermal properties is unnecessary because thermal changes may be based on data for the gaseous state only. Often the laws of a "perfect gas" may be applied and corrections for deviations therefrom made if necessary. Thus, in most engineering calculations, air may be treated as a "perfect gas" although certain industrial processes for the separation of atmospheric air into its components operate only because air is not a "perfect gas."

Thermal Properties of a Perfect Gas

A perfect gas is defined as one having an equation of state represented by the combination of the laws of Boyle and Gay Lussac, namely,

$$p\,v = R\,T$$

and also conforming with Joule's law which states that the internal energy of a perfect gas is a function of it's temperature only. Joule's law is often represented by the mathematical expression

$$\left(\frac{\partial u}{\partial v}\right)_T = O$$

which indicates that the internal energy does not vary with change in volume when the temperature is constant. Joule's law is based on an experiment made by Joule in 1845, in which he connected a vessel A (Fig. 1) containing compressed gas with another vessel B which was nearly empty, by means of a pipe having a closed stop-cock C. Both vessels were immersed in a tank of water and allowed to come to a uniform temperature. Then stop-cock C was opened. The temperature of the water was found to have undergone no appreciable change after the compressed gas had expanded from vessel A into vessel B. Therefore, the gas neither gained nor lost heat during its expansion; and since no external work was done, the internal energy in the gas after expansion must have been the same as before expansion. This led Joule to announce the law stated above for air and other gases. In later experiments by Joule and Thomson, a more delicate method was adopted to detect any change in temperature of a gas undergoing a change in volume, and it was found that the internal energy of air and other gases is not independent of the volume at constant temperature. Joule's law therefore applies only to a perfect gas.

Joule's law is sometimes called the "second law of Gay Lussac" because a somewhat similar experiment was performed by Gay Lussac some years previous to Joule's experiment. The rate of internal energy change of a real gas with change in volume at constant temperature, is called the "Gay Lussac effect." To say that in a perfect gas the "Gay Lussac effect" is zero, is another way of stating Joule's law.

When unit weight of a perfect gas is heated at constant volume, the heat dq applied through a small temperature change dT is given by

$$dq = c_v \, dT$$

where c_v is the specific heat of unit weight of the gas at constant volume. Since no external work is done, the heat added must equal the internal energy change du, that is,

$$du = c_v \, dT$$

If heated under a constant pressure p, the gas will expand an amount dv and perform the external work

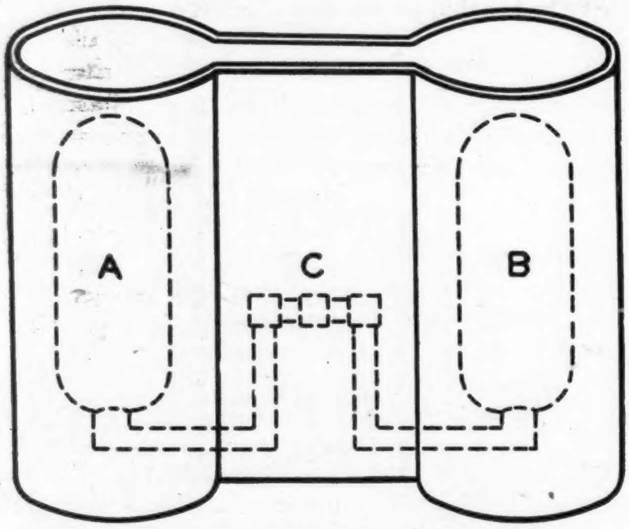


Fig. 1—Apparatus used to demonstrate Joule's law

A p dv measured in heat units. Denoting the specific heat of unit weight of gas under constant pressure by c_p, we have the internal energy change while heating under constant pressure to be

$$du = c_p \, dT - A \, p \, dv$$

By Joule's law, the internal energy of a perfect gas is a function of temperature only; therefore, the internal energy change when heated under constant pressure must be the same as when heated at constant volume for the same temperature change dT; that is, $du = c_v \, dT = c_p \, dT - A \, p \, dv$

or

$$c_p - c_v = A \, p \frac{dv}{dT}$$

From the equation of state for unit weight of a perfect gas, $pv = RT$, we obtain for the rate of volume change with temperature variation under constant pressure $\frac{dv}{dT} = \frac{R}{p}$

Substituting in the above, we get

$$c_p - c_v = A \, R$$

Thus, for a perfect gas, the difference between the specific heats at constant pressure and at constant volume is a constant quantity at all temperatures and is independent of the pressure.

But while the difference between the specific heats must be constant, both specific heats may vary with the temperature and the pressure and the gas still conform with the laws of Joule, Boyle and Gay Lussac. In certain calculations, it is desirable to consider a perfect gas to have constant specific heats as well as to conform with the above mentioned laws. For such a perfect gas, we would have for unit weight of gas:

Specific heat at constant pressure, $c_p = \text{constant}$.
Specific heat at constant volume, $c_v = \text{constant}$.
Ratio of specific heats, $c_p/c_v = k$ (constant).
Difference of specific heats, $c_p - c_v = A \, R$ (constant).
Change in internal energy, $du = c_v \, dT$.
Equation of state, $pv = RT$

These relations may be combined in several ways; thus,

$$c_p = \frac{k \, A \, R}{k-1}$$

$$c_v = \frac{A \, R}{k-1}$$

$$du = \frac{A \, R}{k-1} \, dT$$

The internal energy in unit weight of a perfect gas is by integration of du between the absolute zero and temperature T, assuming the internal energy to be zero at the absolute zero of temperature,

$$u = \frac{ART}{k-1} = \frac{A \, p \, v}{k-1} = c_v \, T$$

The "total heat" of unit weight of a perfect gas is by definition

$$h = u + A \, p \, v = u + ART = \frac{k \, ART}{k-1} = c_p \, T$$

The heat added to unit weight of a perfect gas is

$$dq = du + A \, pdv = c_v \, dT + A \, p \, dv = c_p \, dT - A \, v \, dp$$

The change in entropy of unit weight is given by

$$ds = \frac{dq}{T} = c_v \frac{dT}{T} + A \, R \frac{dv}{v}$$
$$= c_p \frac{dT}{T} - A \, R \frac{dp}{p}$$

The entropy of unit weight at any temperature and volume or pressure is by integration of the above expression,

$$s = c_v \log_e T + A \, R \log_e v + s_o$$
$$= c_p \log_e T - A \, R \log_e p + s_o$$

where s_o is the constant of integration and represents the entropy at some reference temperature and volume or pressure.

As an illustration of the use of the above relations, we will determine the thermal properties of dry atmospheric air considered as a perfect gas at a temperature of 100 fahr. and under 50 lb. per sq. in. absolute pressure. Take $R = 53.36$ ft.-lb. per deg. fahr. per lb. of dry air and $k = 1.400$. Then,

$$c_v = \frac{53.36}{778.6 \, (1.400 - 1)} = 0.1713 \text{ B.t.u. per lb. per deg. fahr.}$$

$c_p = 0.1713 \times 1.400 = 0.2398$ B.t.u. per lb. per deg. fahr.
$u = 0.1713 \times (100 + 459.6) = 95.9$ B.t.u. per lb.
$h = 0.2398 \times (100 + 459.6) = 134.2$ B.t.u. per lb.

$$s = 0.2398 \log_e 559.6 - \frac{53.36}{778.6} \log_e (144 \times 50) + s_0$$
$$= 2.126 + s_0 \text{ B.t.u. per lb. per deg. fahr. abs.}$$

Specific Heats of Real Gases

In many engineering calculations, the specific heats of the real gases involved may be taken as

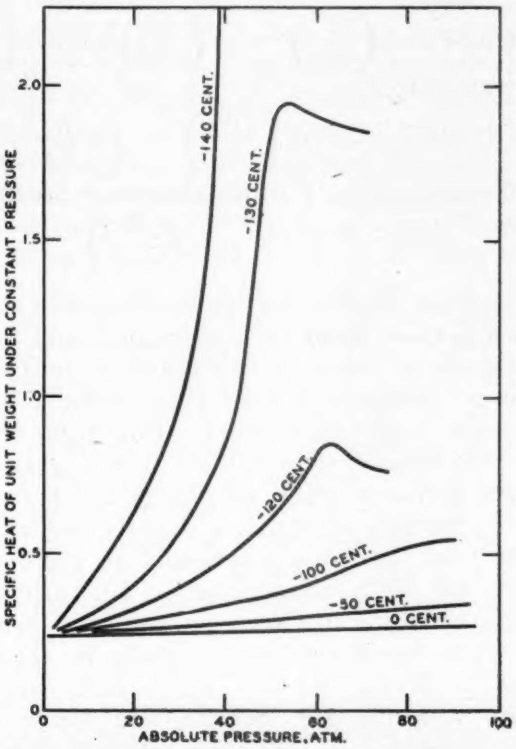


Fig. 2—Specific heat of air under constant pressure at low temperatures as calculated by Witkowski

constant. Thus, for atmospheric air, the following values are often used:

$c_p = 0.24$ B.t.u. per lb. per deg. fahr.
$c_v = 0.17$ B.t.u. per lb. per deg. fahr.
$k = c_p/c_v = 1.40$

Except for monatomic gases, the use of constant values for the specific heats and for the ratio between them is an approximation only. The kinetic theory of gases indicates that for a monatomic gas,

$$C_p = \frac{5}{2} A R; \quad C_v = \frac{3}{2} A R; \quad k = \frac{5}{3}$$

Since A R = 1.985 B.t.u. per lb.-mole per deg. fahr. for all gases, as will be shown in a future article, we have for monatomic gases,

$C_p = \frac{5}{2} \times 1.985 = 4.96$ B.t.u. per lb.-mole per degree fahr.

$C_v = \frac{3}{2} \times 1.985 = 2.98$ B.t.u. per lb.-mole per degree fahr.

$k = 5/3$

Experiments on mercury, argon, helium and other monatomic gases show that the above values are nearly true at all temperatures except near the point of liquefaction. For gases with more complicated molecular structures, the specific heats vary with temperature and also with the pressure to which the gases are subjected. For atmospheric air, the variations of c_p and c_v with pressure are shown in Fig. 2 and Fig. 3 respectively as calculated by Witkowski for temperatures of zero centigrade and below. The nearly horizontal lines for zero centigrade show that for this temperature and above, the variation with pressure is negligible in most engineering calculations. The variation with temperature is not negligible, however, as will be shown by tabulated values of the specific heats of some of the most common gases. The ratio of the two specific heats also varies considerably with temperature, but the difference between them may generally be taken the same at all temperatures above atmospheric.

Instead of using the specific heat of unit weight of a gas, it often is more convenient to employ the specific heat of the molecular weight, or one mole, of the gas. The difference between the specific heats at constant pressure and at constant volume may then be taken the same for all gases because A R has the

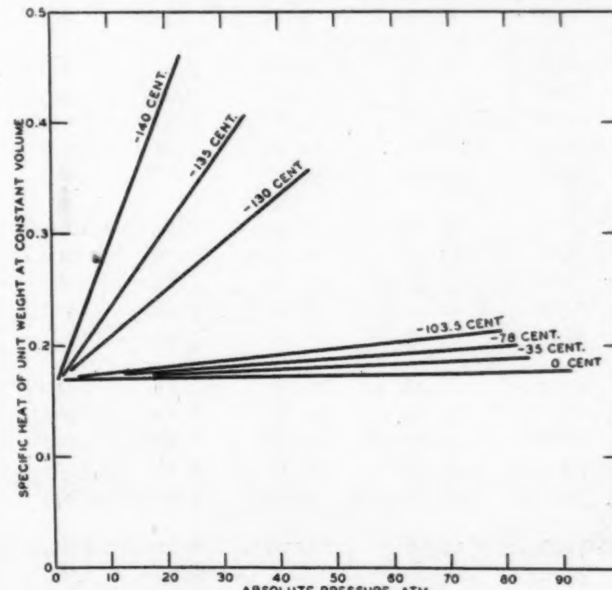


Fig. 3—Specific heat of air at constant volume at low temperatures as calculated by Witkowski

same value for one mole of all gases; that is, $C_p - C_v$ = A R = 1.985 B.t.u. per lb.-mole per deg. fahr. Also, the specific heats of the diatomic gases, nitrogen, oxygen and carbon monoxide, may be taken the same if based on one mole of gas rather than on unit weight. In dealing with gaseous mixtures, specific heats of the components based on one mole are particularly convenient.

In Table I, will be found the specific heats under constant pressure per mole of carbon dioxide, of water vapor, and of the diatomic gases, nitrogen, oxygen, and carbon monoxide. The specific heats

at constant volume may be found by substracting 1.985 from the tabulated values. The tabulated values may be taken as B.t.u. per lb.-mole per deg.

TABLE I. SPECIFIC HEATS OF GASES UNDER CONSTANT PRESSURE

B. t. u. per lb.-mole per deg. fahr. or cal. per gm.-mole per deg. cent.

Temperature fahr.	CO_2	H_2O	N_2, O_2, CO_2 (dry air)	Temperature cent.
0	8.62	8.29	6.96	—18
100	9.01	8.31	6.97	38
200	9.38	8.33	6.98	93
300	9.73	8.36	7.00	149
400	10.05	8.41	7.02	204
500	10.36	8.46	7.04	260
600	10.65	8.51	7.07	316
700	10.92	8.58	7.09	371
800	11.17	8.65	7.12	427
900	11.40	8.74	7.15	482
1000	11.62	8.83	7.19	538
1100	11.83	8.93	7.22	593
1200	12.02	9.04	7.26	649
1300	12.19	9.15	7.30	704
1400	12.35	9.28	7.35	760
1500	12.50	9.41	7.39	816
1600	12.64	9.56	7.44	871
1700	12.76	9.71	7.49	927
1800	12.88	9.87	7.54	982
1900	12.98	10.03	7.60	1038
2000	13.08	10.21	7.66	1093
2100	13.16	10.40	7.72	1149
2200	13.24	10.59	7.78	1204
2300	13.31	10.79	7.84	1260
2400	13.37	11.00	7.91	1316
2500	13.43	11.22	7.98	1371
2600	13.48	11.45	8.05	1427
2700	13.52	11.68	8.13	1482
2800	13.56	11.92	8.21	1538
2900	13.60	12.18	8.28	1593
3000	13.63	12.44	8.37	1649
3100	13.66	12.71	8.45	1704
3200	13.69	12.98	8.54	1760
3300	13.72	13.27	8.63	1816
3400	13.75	13.57	8.72	1871
3500	13.78	13.87	8.81	1927
3600	13.81	14.18	8.91	1982
3700	13.84	14.50	9.01	2038
3800	13.87	14.83	9.11	2093
3900	13.91	15.17	9.21	2149
4000	13.95	15.51	9.32	2204

fahr. at the fahrenheit temperatures given or as cal. per gram-mole per deg. cent. at the corresponding centigrade temperatures. To obtain the specific heat per unit weight of gas, divide the tabulated values by 44 for carbon dioxide, by 18 for water vapor, by 28 for nitrogen, by 32 for oxygen and by 28 for carbon monoxide. The specific heat of unit weight of dry atmospheric air may be obtained by dividing the specific heat for the diatomic gases by 28.97, the equivalent molecular weight of dry atmospheric air.

The tabulated values were calculated by the following formulas derived by Goodenough and Felbeck for the molecular specific heats in terms of the absolute temperature T in degrees fahr. absolute:
For carbon dioxide,

$$C_p = 6.548 + 5.067\left(\frac{T}{1000}\right) - 1.248\left(\frac{T}{1000}\right)^2 + 0.1085\left(\frac{T}{1000}\right)^3$$

For water vapor,

$$C_p = 8.33 - 0.276\left(\frac{T}{1000}\right) + 0.423\left(\frac{T}{1000}\right)^2$$

For diatomic gases, nitrogen, oxygen, carbon monoxide,

$$C_p = 6.93 + 0.1200\left(\frac{T}{1000}\right)^2$$

For carbon dioxide, the first term has been changed from 6.4587 as given by Goodenough and Felbeck because their value is apparently a misprint as found by comparison with their formula for the centigrade temperature scale. Also, slight changes have been made in the constants in two other terms. For the diatomic gases, no change has been made in their formula although a slightly higher value of the first term would probably be more nearly correct for room temperatures. The formula as written gives specific heats around room temperature which correspond very closely to those obtained by Swann for dry atmospheric air. For oxygen and nitrogen, Scheele and Heuse found values somewhat higher than Swann's values for dry air by an amount which may be accounted for by the percentage of argon in atmospheric air. But as the formula will generally be used for atmospheric air and for the products of combustion of fuels with atmospheric air, the nitrogen involved will contain this argon as an impurity. Consequently, the formula as given will more nearly represent the conditions to which it will be applied than if it were modified to be more nearly correct for pure oxygen and nitrogen.

The above formulas for specific heats of gases were based on recent experimental work. The first published data on specific heats of gases appeared in 1788 under the title, "Experiments and Observations on Animal Heat," by Crawford. The gases were heated in cylindrical vessels of very thin sheet brass which were immersed in water and the rise in temperature noted. Lavoisier and Laplace about the same time made experiments on the specific heats of gases by passing them through a long spiral tube embedded in ice and noting the drop in temperature. Delaroche and Berard immersed the tube in a bath of water and measured its rise in temperature for the passage of a given quantity of

gas. Gay Lussac and several others made experiments on the specific heats of gases during the first half of the 19th century, but all these early experiments contained large errors due to the crude apparatus employed, to the absence of definite temperature standards and to a lack of knowledge concerning the corrections necessary for the experimental procedure employed.

In 1862 appeared the classical work of Regnault on the specific heats of gases. While Regnault's work was done with the greatest care possible at the time, it has since been learned that small corrections should be applied, but these corrections cannot now be made because certain constants for his experimental apparatus are unknown. Regnault passed gas from a holder at a known temperature through a coil immersed in water and measured the rise in water temperature and the fall in gas temperature for the passage of a given quantity of gas.

The most accurate method of determining the specific heat of a gas under constant pressure is to pass the gas through an electrically heated tube and measure the heat added electrically, the rise in gas temperature and the rate of gas flow. This method was devised by Callendar and improved by Barnes and is consequently known as the Callendar-Barnes method. This method was used by Holborn and Austin to measure the specific heats of gases up to 800 cent., the results of their experiments being published in 1905. The apparatus was later improved by Holborn and Henning and measurements made to 1400 cent. Similar apparatus was used by Holborn and Jacob to measure specific heats under high pressures. Swann applied this flow method in 1909 to very accurate determinations for dry air and for carbon dioxide at 20 and 100 cent. The same method was used by Scheel and Heuse for measurements at and below room temperatures upon a number of gases, their data being published in 1912, 1913 and 1919.

For very high temperatures, the specific heats of gases have been measured by the "explosion" method in which a known volume of explosive gas is mixed with a known volume of inert gas and the maximum pressure noted when the mixture is exploded in a vessel of constant volume. This method was originated by Bunsen in 1883 and has since been applied by Mallard and Le Chatelier, by Langen, by Pier, by Bjerrum, by Womersley and by others. The earlier results by Mallard and Le Chatelier and by Langen are of little value due to indeterminate errors.

The ratios of the two specific heats at constant pressure and at constant volume have been determined for various gases by measurements of the velocities of sound in these gases. Sound waves are propagated by alternate adiabatic expansion and compression of a gas as first pointed out by Laplace; and as the relation between pressure and volume during adiabatic change is a function of the ratio of the specific heats, this ratio may be calculated from measurements of the velocity of sound.

Entropy of Real Gases

If in the expression previously given for the entropy of a perfect gas, the temperature be taken as absolute zero, the entropy will be found to be minus infinity; that is, the entropy of a perfect gas becomes less than zero as the gas is cooled to very low temperatures. If real gases are cooled, they do not remain in gaseous form but they first become liquid and then the liquid solidifies generally into a crystalline solid before the absolute zero of temperature is reached. Nernst in 1906 announced a general principle which is equivalent to the statement that the entropy and also the specific heat of a solid approach zero as the temperature is reduced to the absolute zero. Experiments on solids at very low temperatures have since indicated the truth of the Nernst heat theorem, although there exists some belief that in non-crystalline solids, if not in all solids, some positive entropy and internal energy exist at the absolute zero. It is generally accepted, however, that the entropy never becomes negative. At very low temperatures, the specific heat of a crystalline solid varies as the cube of its absolute temperature as first derived theoretically by Debeye

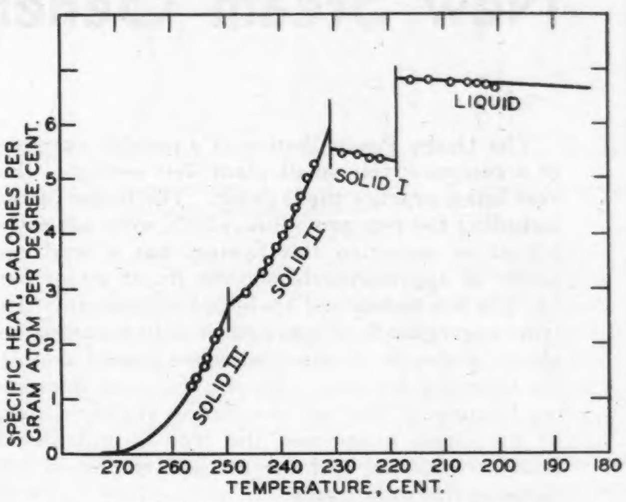


Fig. 4—Specific heats of liquid and solid oxygen at very low temperatures from Eucken

in 1912 and later established experimentally. For oxygen, the specific heats of the liquid and solid forms at very low temperatures are shown in Fig. 4 from the work of Eucken.

Reckoned from the absolute zero of temperature, every real gas therefore has a definite quantity of entropy at each temperature and pressure as well as a definite amount of heat added under constant pressure. This third law of thermodynamics is stated by Lewis and Randall as follows: "If the entropy of each element in some crystalline state be taken as zero at the absolute zero of temperature: every substance has a finite positive entropy, but at the ab-

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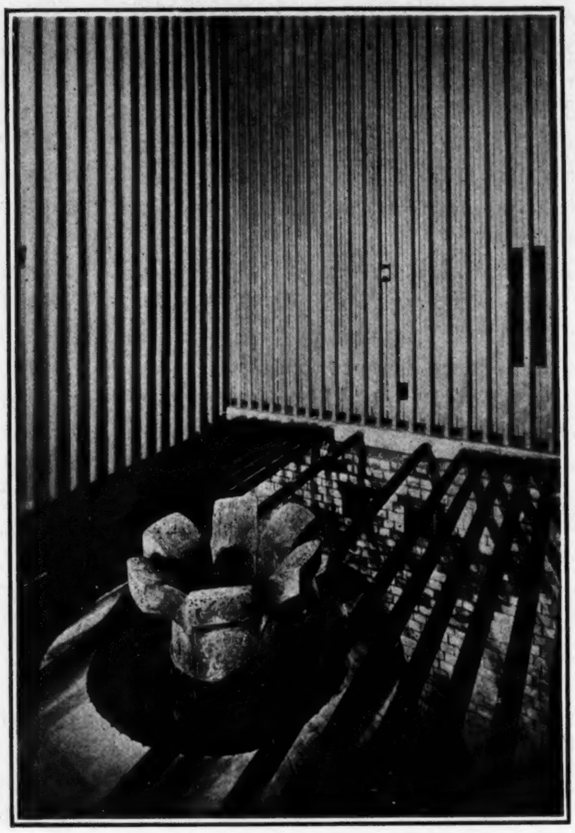

Fig. 1—Interior of steam generator at Derby showing arrangement of "volcano" type burner

Description of New Steam Generators at Derby Station

By DAVID BROWNLIE, London

The Derby Power Station is a notable example of a comparatively small plant that embodies the very latest practice throughout. The boiler plant, including the two new units, which were officially placed in operation this Spring, has a total capacity of approximately 400,000 lb. of steam per hr. The five pulverized fuel-fired units occupy the same aggregate floor space previously occupied by eleven stoker-fired units, but have nearly double the steaming capacity. Among the most interesting features of the new installation are the design of the steam generators, the type of pulverized fuel burner used and the method employed for cleaning the stack gases.

ON March 28, 1930, the 1929-30 extension to the Derby Power Station, Derby, England was officially opened. This extension included two new steam generating units of the most modern design, with a capacity of 60,000 to 80,000 lb. of steam per hr. each. These units operate at 350 lb. pressure and from 700 to 750 deg. fahr. steam temperature. They are equipped with both air preheaters and economizers and are fired by a recently developed turbulent burner known as the "Volcano" type, which is located in the bottom of the combustion chamber between the water screen tubes, and fires directly upward.

The Derby Station was one of the first British power stations to use pulverized fuel firing. In 1924 a new boiler house was built on the site of the old plant, which had included six Lancashire boilers with a capacity of 42,000 lb. of steam per hour each. The first section of the new plant included three boilers of cross drum type containing 8,851 sq. ft. of heating surface each and operating at 300 lb. pressure and at approximately the same capacity range as the latest units (60,000 to 80,000 lb. of steam per hr.). The furnace walls were of the air-cooled, refractory type equipped with water screens across the bottom and over the rear wall. Six vertical burners of the fish tail type were installed in each furnace. The pulverizing and feeding equipment followed the more or less standard practice of that time, including roller mills and screw feeders. Steam dryers were installed to reduce the moisture content of the coal from 14 per cent to approximately 2 per cent.

A third unit, installed in 1927, was quite similar in design except that water surface in the form of plain steel tubes was installed over the furnace side walls, the tubes spaced on 14 in. centers, and a water screen of the fin tube construction was installed in the back wall. Duplex horizontal plate type feeders were installed, together with a more modern

type of steam dryer, the earlier dryers also being remodeled to conform to the new design.

The two new units which have just been placed in operation are said to be different from any units in operation in Great Britain at the present time. They are of the Combustion Steam Generator type, designed by Combustion Steam Generator Limited. The four walls of the combustion chamber consist of fin tubes with a water screen at the bottom and four rows of plain tubes at the top, above which the superheater is suspended. There is no brick work whatever in the construction of the furnace.

A steam and water drum connected to the rear wall tubes is placed across the top of the boiler. The wall tubes are expanded at the bottom ends into four horizontal headers and the front and rear wall headers are connected by the water screen which slopes upwards towards the front of the boiler. The front wall tubes terminate at their upper ends in separate vertical headers connected to the steam and water drum by the four rows of tubes forming the roof, which rise slightly towards the back of the boiler and then turn upwards into the drum. The side walls enter horizontal headers above the superheater and curved tubes connecting the headers to the steam and water drum form a roof over the complete boiler.

Water is fed to the rear wall by a set of plain tubes between the drum and the bottom header, insulated from the furnace by the rear wall and also by a thin brickwork partition. The wall of the downcomer tubes also feeds the water screen and front wall. Two pipes of large bore, external to the boiler, feed the bottom side wall headers, and

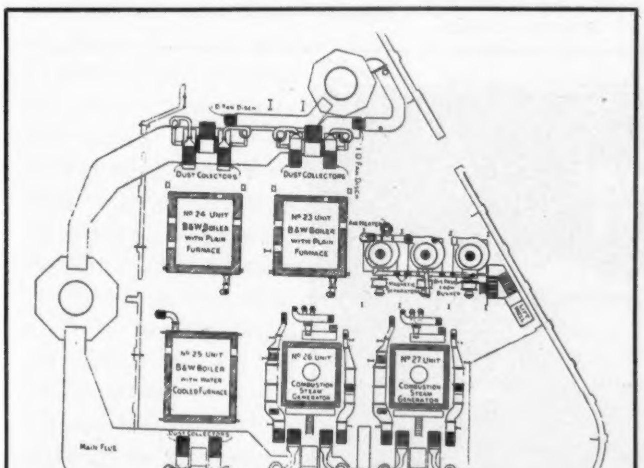

Fig. 2—Plan view of boiler plant

this water is returned through the tubes forming the roof of the boiler.

The design insures positive and vigorous circulation, as all areas are generously proportioned, and the whole of the heating surface is disposed in such a manner that heat absorption is spread evenly over all sections, resulting in maximum heat transfer.

A system of special baffling in the steam and water drum separates water from the steam generated in the boiler, but to insure dry vapor passing to the superheater, the steam first enters a receiver immediately over the boiler drum where, owing to the low velocity, any suspended moisture is deposited.

The whole of the pressure parts are supported by

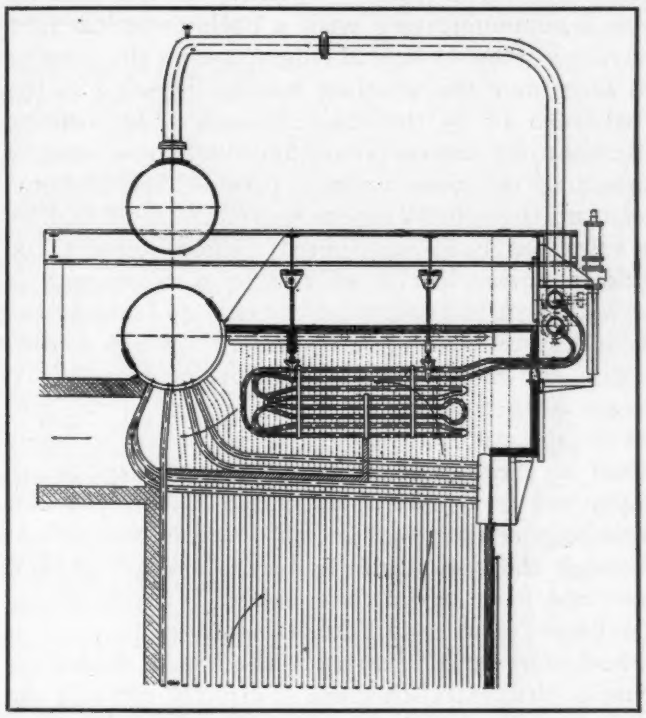

Fig. 3—Sectional elevation of upper part of steam generator showing arrangement of superheater

an independent steel structure, adequate provisions being made for expansion in all directions.

The steam generator is enclosed by a steel casing lined with insulating material, the only portions of the boiler outside the casings being the side wall feeding pipes and the drums, which are adequately insulated. The boiler casing is built up of panels secured to steel work carried by the boiler structure, and observation doors are provided where necessary for inspecting conditions in the combustion chamber, the tube fins being cut away behind them to provide free vision.

The superheaters have been specially designed for the steam generators and are arranged as shown in Fig. 3. They are of the convection type, each containing 1,580 sq. ft. of heating surface, having 40 single pass multiple loop elements 95 ft. in length, made from solid, cold-drawn, mild steel tubing Any element can be removed without injury to the tube or joint, and handhole fittings are not required. The superheaters are carried from the structure supporting the boilers, no weight whatever being imposed upon the boiler tubes. Each element is individually carried by heat resisting steel alloy hangers, and bands and spacers are also fitted to prevent sagging or distortion of the tubes.

Each boiler unit is equipped with one burner of "Volcano" pattern, built up from the floor of the ash pit and projecting into the combustion chamber through the water screen, the tubes of the latter being arranged to suit. A photograph of one of the burners, as installed, is shown in Fig. 1.

The Volcano burner is an adaptation of the type "R" burner, and embodies many of its distinctive features. As in the type "R" burner, the fuel enters a volute communicating with a hollow conical tube having a series of helical ridges cast on the interior to accentuate the whirling motion imparted to the coal-laden air by the volute chamber. On leaving the cone the current is confined within a vertical tube until the water screen is passed. Near the outlet from the central tube a restriction is formed by a cast iron bush, rifle-bored, which restores the helical motion lost by friction, and its position is such that the expansion of the coal and air current following the restriction insures a thorough spreading of the fuel over the edges of the burner. To create further turbulence in the centre of the fuel jet a cast iron ring with internal helical vanes is fitted to the burner outlet. The two castings are supported on a central spindle and their position may be regulated by a system of levers passing out through the bottom of the burner and ash pit and operated from outside the boiler. By this means the burner is under full control at all loads.

Secondary air is admitted to the base of the burner outside the central tube and is directed towards the mouth of the burner by a brickwork cone cut off just below the water screen. The top of the central tube is belled out and cut away as will be seen from the illustration, Fig. 1, and the helical motion of the coal and air stream, aided by the expansion following the constriction below the outlet, causes the fuel to spread out, due to centrifugal action, immediately upon reaching the burner mouth. The upward flow of secondary air through the spreading coal layer insures an intimate mixture of fuel and air and creates the conditions necessary for instantaneous combustion.

In order to accentuate turbulence in the part of the furnace near the burner and to provide the additional air necessary at very high loads, secondary air ports are provided in each wall of the combustion chamber about 3 ft. above the water screen and 3 ft. 6 in. from the center line, the air currents proceeding from them being tangential to a circle 7 ft. diameter and producing a cyclonic motion in the gases rising through the furnace.

The combined effect is to produce an intense flame low down in the combustion chamber with the result that combustion is complete before the gases leave the furnace. The degree to which perfect combustion conditions are approached may be judged from the fact that 16.5 per cent CO_2 has been obtained without difficulty, a remarkable figure when compared to the ideal content of 18 per cent which is the theoretical CO_2 content for the class of fuel used. The high temperature corresponding to this percentage of CO_2 is such that only a boiler designed on the lines of the new units can properly utilize it.

The feed water economizers are mounted at the back of the units just below the flue gas exits. They are of the steaming type, manufactured by Eco Power, Ltd. Cast iron gills are shrunk on the outside of

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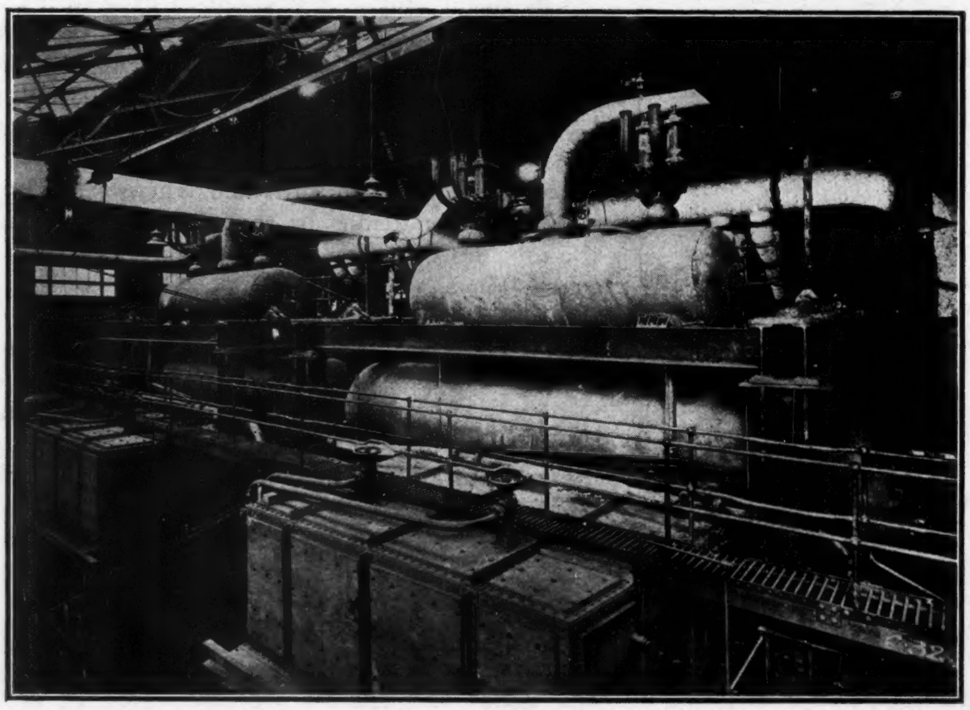

Fig. 4—View of upper part of two steam generators recently installed at Derby Station

The East River Generating Station of the New York Edison Company*

BY C. B. GRADY,[1] W. H. LAWRENCE,[2] and R. H. TAPSCOTT[3]

This paper deals with the design and operating characteristics of the East River Station of the New York Edison Company. In addition to descriptions of principal equipment and operating and test data, the authors present some of the major considerations influencing the decisions reached on various aspects of design. The East River Station is designed for an ultimate capacity of 1,240,000 kw. and occupies a site approximately a quarter of a mile long by 200 feet wide. In 1929 the three largest steam generating units ever built were installed in this station. On a recent test, one of these units evaporated 1,000,000 lb. of steam per hr. for twelve consecutive hours. A heat balance of this run is given in this article indicating an efficiency of 86.5 per cent at an output 25 per cent above the maximum guaranteed capacities. Evaporations considerably in excess of 1,000,000 lb. of steam per hour have been obtained for shorter periods.

In a brief synopsis of this article, the authors present the following summary of unusual features:

- **The location of all of the circulating water pumps in a pit at the river end of the station, each set of pumps supplying its condenser through cast iron circulating water pipes six feet in diameter.**
- **The adoption of steam turbine drive for the essential auxiliaries.**
- **The adoption of pulverized fuel firing in what had hitherto been an exclusively stoker territory.**
- **The burning of pulverized coal in completely water cooled furnaces containing practically no refractories.**
- **The use of the largest boilers yet built.**
- **The first use of a double winding generator which is also the largest generator in operation.**

THE New York Edison Company and affiliated companies operate two 25-cycle stations aggregating 402,000 kw., four combined 25- and 60-cycle stations aggregating 1,110,000 kw., and two 60-cycle stations aggregating 405,000 kw., a total generating capacity of 1,917,000 kw. with a 1929 peak load of 1,225,200 kw.

All stations are interconnected by means of tie feeders which approximate, in each instance, the capacity of the largest unit. Five frequency changers with a total capacity of 190,000 kw. tie the 25- and 60-cycle systems.

The 25-cycle system is operated radially, the high-tension feeders not normally being paralleled on the a-c. side of the rotary converters at the substations. The substations are usually supplied from more than one generating station to assure continuity and to facilitate load transfer.

The 60-cycle system is operated in parellel at the load (synchronized at the load), each section in a generating station being considered electrically as a separate station with ties only at the substation low-voltage busses or at the network.

At the time East River Station was designed, Manhattan Island was served almost exclusively from the 25-cycle system with conversion to direct current. The policy of the company at the present time, however, is to curtail the d-c. load in favor of the 60-cycle network. This paper deals with the development of the East River station as originally planned under a proposed growth of the 25-cycle system. Under the present policy of the company, no additional 25-cycle units will be installed, and the future development of the station will be devoted exclusively to 60 cycles. It is estimated that in 10 years the 60-cycle load of the New York Edison System will be at least four times the 25-cycle load.

Site

There were very few areas on Manhattan Island where sufficient space together with other essential requirements satisfied the specifications for the station contemplated. The site chosen has the following advantages: it is near the center of the Manhattan load; it provides a continuous area for future expansion both as to buildings and high-tension feeder outlets; favorable waterfront conditions provide ample depth, some 30 ft., for docking ocean going colliers and for large disposal of ashes.

The arrangement of the buildings and structures is shown in Fig. 1. The generating plant, which lies between 14th and 15th Streets, Avenue C and the East River, will be 1092 ft. long and 206 ft. wide.

Coal Handling and Preparation

The coal is at present brought to the station in 1000-ton barges and unloaded by two electric traveling coal towers each having a capacity of 350 tons

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per hour. The coal is crushed in the towers and discharged to belt conveyors for delivery to the 5000-ton bunker in the coal preparation house.

The pulverizing equipment consists of two 15-ton and four 25-ton Raymond air-swept mills, the drying being accomplished therein by the admission of preheated air. The coal is fed into these mills by gravity through individual chutes from the raw coal bunker, the quantity being regulated by star feeders of which there are two per mill. Each mill has six rollers, 20 in. in diameter, each weighing 700 lb.

The air required by each 15-ton mill is supplied by a 28,000 cu. ft. per min. constant speed, motor-driven fan which operates in a closed system comprising the mill, the cyclone separator, and the fan. Adequate drying of the coal is obtained by means of preheated air drawn by a 14,000 cu. ft. per min. fan through a low pressure heater at 15 lb. gage and a high pressure heater at 400 lb. gage. The temperature of the air and coal leaving the mill does not exceed 105 deg. fahr. To compensate for this hot air introduced, an equal amount is exhausted from the system by another 14,000-cu.-ft.-per-min. fan. This exhausted air is passed through an additional cyclone separator for removal of the coal, which is led back into the system, while the air is vented through a U-shaped water spray air washer, (Fig. 2). With this method of coal drying, precautions must always be taken to start the heater fan before turning on the steam to the heaters to prevent fires due to dust collection on the tubes.

The arrangement of the 25-ton mills is similar, their larger fans being equipped with variable-speed instead of constant-speed motors.

The coal collected in the cyclone separator of the closed system flows by gravity into a transport pump which conveys it to the boiler coal bins. One 100-ton coal bin is provided for each of the original boilers and two for each of the new boilers.

The average fineness of the coal is approximately 96 per cent through a 60-mesh, 90 per cent through a 100-mesh, and 70 per cent through a 200-mesh sieve. The moisture content of the coal affects the capacity of the mills to a certain extent but the grain characteristics of the coal itself have a far greater effect than the varying surface moisture.

Boilers and Fuel Burning System

The initial boiler installation consisted of six 14,809-sq.-ft., Springfield, horizontal cross-drum boilers, 4134 sq. ft. of water wall surface on all four sides of the furnace and a slag screen above the ash pit. The superheater contains 3430 sq. ft. of heating surface and is of the hairpin type, while the air preheater contains 28,900 sq. ft. of effective heating surface and is of the stationary plate type. The Lopulco system of vertical firing with ten main burners and ten auxiliary burners is used (Fig. 3).

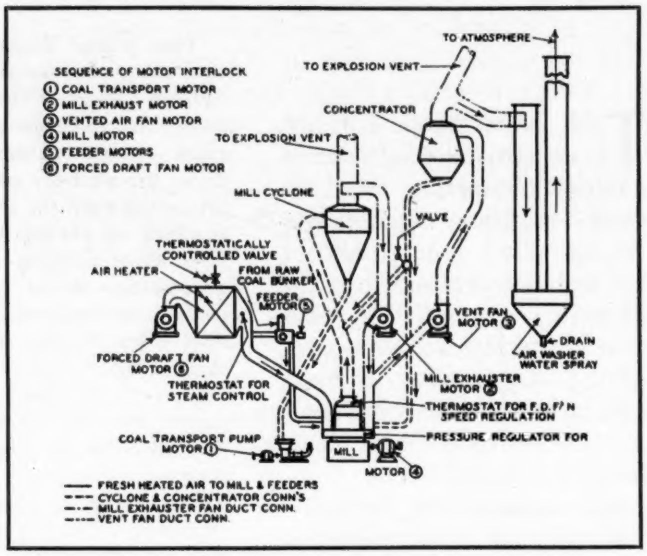


Fig. 2—Arrangement of equipment comprising 25-ton pulverizing mill

The new installation consists of three 800,000-lb. per-hr. boilers of the Ladd type fired from both ends. Each boiler contains 60,706 sq. ft. of heating surface

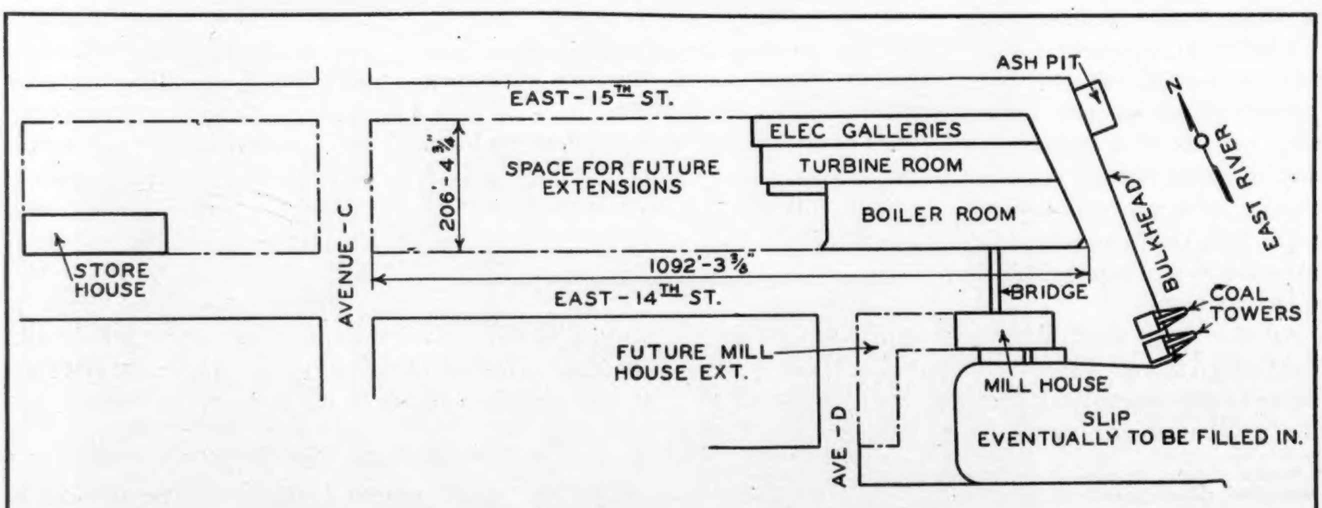


Fig. 1—Arrangement of buildings on site

and 7345 sq. ft. of water wall surface on all four sides of the furnace, with a slag screen above the ash pit (Fig. 4). The superheater contains 13,900 sq. ft. of heating surface and is of the hairpin type. The air preheater contains 82,721 sq. ft. of effective heating surface and is of the plate type. The furnace has a volume of 38,200 cu. ft. with a heat liberation of 29,300 B.t.u. per cu. ft. of furnace volume when operating at 800,000 lb. steam per hour. The steam conditions are 425 lb. gage pressure with 725 deg. fahr. total temperature, and feed water temperature of 360 deg. fahr. at 800,000 lb. per hour evaporation. The air temperature leaving the air preheater at this rating is 450 deg. fahr. The Lopulco system of vertical firing is used, with a total of 20 main and 20 auxiliary burners, or 10 of each on each end.

Subsequent to the initial starting period, operating difficulties have been of a minor nature, little clinker trouble having been experienced either on the boiler tubes or the lower water wall headers. Any accumulation of ash or slag on the lower headers or sides of the ash pit is removed by means of a hand lance, while the boiler is in operation. Experience with

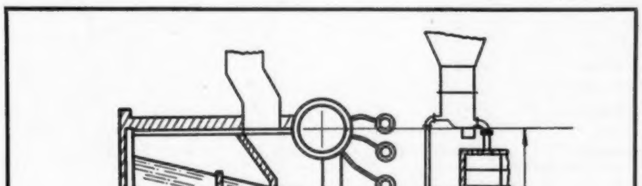


Fig. 3—Sectional elevation of one of old boiler units

the fin type tube indicates that the fins should not exceed one inch in width.

Some trouble was experienced in maintaining the water level in the top drum of the boilers but the addition of a plate baffle in the drums has corrected this condition for any load up to 600 per cent of boiler rating. The normal operating rate of these boilers is approximately 350 to 400 per cent. Table 1 gives the principal data from a test of No. 4 boiler.

Superheaters are installed in all boilers. The results obtained have been on the whole satisfactory, both as to the superheat output conditions and maintenance. The main trouble experienced has been leaking of ball and socket joints, since remedied by the use of copper gaskets.

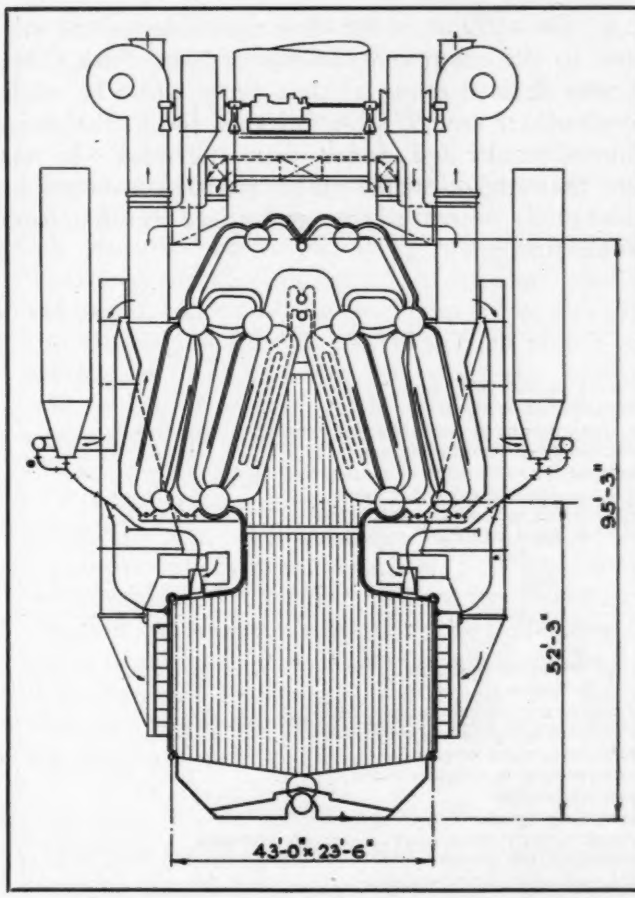


Fig. 4—Sectional elevation of one of new boiler units

The plate type air preheaters have given very good service. No sticking of clinkers has been experienced, nor have any elements required replacement since the station has been in operation. The passage of cinders with the gases has kept the plates clean, and there has been no evidence of corrosion or erosion.

The draft equipment which consists of induced draft, primary, and secondary air fans has given very good service. The only trouble experienced is with the induced draft fans, the blades and scroll linings of which have to be replaced every two years due to the erosive action of the cinders.

Pulverized fuel was adopted for this station for the following reasons:

1. It was believed that this type of firing would permit a very much larger field from which to purchase suitable coal and that high efficiencies could be maintained with some of the cheaper grades of coal which can be burned only with great difficulty on stokers.

2. Our experience with large stoker fired boilers indicated that with such equipment, we must expect to have from 10 to 15 per cent of the boiler capacity continuously out of service for repairs. It was felt that with pulverized fuel firing, this outage would be very largely eliminated, resulting in the installation of less boiler capacity to meet a given load.

3. The experience of others in burning pulverized fuel indicated a much flatter efficiency curve than with stoker firing.

4. On account of the close proximity of the station to the congested sections of New York City, it was deemed essential that every effort be made to eliminate any possible nuisance due to the emission of smoke and cinders from the stack. It was felt that objectionable stack discharges would be more easily controlled from pulverized fuel than from stoker firing.

Our operating experience to date indicates that the field from which we can buy our coal supply includes any place in the world that can produce coal. We are now buying coal of equal heat value for this station at a cost of 24 cents per ton less than we are paying for stoker plants. This differential more than offsets the cost of coal preparation which averages about 18.5 cents per ton including labor, maintenance and power (at fuel cost) and in addition to this advantage, the repairs to the boiler and furnace due to the use of the completely water-cooled walls, is almost nothing compared to the repair costs on stoker fired plants.

The degree in which our expectations have been realized in the elimination of boiler outage for repairs, is illustrated by the fact that for a period of eight months last year, none of the boilers in this station was out for repairs other than between

TABLE I—RESULTS OF TESTS OF NO. 4 BOILER

		April 23, 1929	May 7, 1929	May 14, 1929
Actual evaporation per hour	lb.	108,630	169,100	239,720
Heat absorbed by steam	per cent	86.1	87.1	84.1
Heat absorbed by air preheater and returned to other boilers	per cent	2.0	0.5	1.0
Heat loss due to moisture in coal	per cent	0.2	0.3	0.2
Heat loss due to moisture in burning hydrogen	per cent	3.2	3.2	3.1
Heat loss due to dry chimney gases	per cent	6.0	7.3	6.1
Heat loss due to combustible in refuse	per cent	0.8	0.8	2.5
Heat loss due to radiation and unaccounted for	per cent	1.7	0.8	3.0
Total	per cent	100.0	100.0	100.0

		April 23, 1929	May 7, 1929	May 14, 1929
Actual evaporation per hour	lb.	108,630	169,100	239,720
Boiler horsepower		3,545	5,715	7,885
Per cent rating (including water walls)		187	302	416
Per cent rating (excluding water walls)		240	386	532
Steam pressure, boiler-gage	lb. per sq. in.	404	414	425
Steam pressure, superheater outlet	lb. per sq. in.	398	399	400
Steam temperature	deg. fahr.	685	711	710
Air to air preheater	deg. fahr.	106	108	111
Average temperature of gases leaving air preheater	deg. fahr.	328	382	368
Temperature feed water	deg. fahr.	293	294	298
Fuel, as fired per hour (weighed)	lb.	10,030	15,650	22,200
Fuel dry, per hour	lb.	9,740	15,060	21,080
Combustion space per lb. dry coal	cu. ft.	1.63	1.05	0.73
Actual evaporation per lb. dry fuel	lb.	11.15	11.23	10.99
Actual evaporation per lb. fuel as fired	lb.	10.82	10.80	10.80
Factor of evaporation		1.126	1.137	1.135
Equivalent evaporation per lb. dry fuel	lb.	12.48	12.76	12.47
Thousands B.t.u. absorbed per hour		118,730	186,520	263,810
Thousands B.t.u. absorbed per sq. ft. boiler heating surface including water walls		6.27	10.40	14.37
Refuse, per cent of fuel, dry		9.1	8.7	10.4
Per cent combustible in ash to ash pit		1.0	0.8	2.1
Per cent combustible in fly ash		9.7	10.0	25.8
Per cent combustible in refuse		8.8	9.1	23.3

		Semi-bituminous storage	Semi-bituminous storage	Semi-bituminous fresh mined
Proximate analysis dry:				
Volatile matter	per cent	18.8	19.2	19.5
Ash	per cent	8.3	7.9	8.0
Fixed carbon	per cent	72.9	72.9	72.5
Moisture—as fired	per cent	2.9	3.8	1.9
Heating value per lb. dry	B.t.u.	14,140	14,220	14,410
Ultimate analysis:				
Carbon	per cent	80.65	80.60	80.70
Hydrogen	per cent	4.25	4.28	4.29
Oxygen	per cent	4.70	5.22	4.38
Nitrogen	per cent	1.25	1.22	1.25
Sulphur	per cent	6.89	0.78	1.36
Ash	per cent	8.28	7.90	8.02
Fineness:				
Through 60 mesh screen	per cent	92	95	80
100 mesh screen	per cent	85	89	69
200 mesh screen	per cent	72	73	54

midnight and 6 a.m. on weekdays and on Sunday during periods of light load.

It will be seen from Table 1, that the small boilers have a very flat efficiency curve, there being only 2 per cent difference in efficiency between an output of 108,000 lb. of steam per hour and an output of 240,000 lb. of steam per hour.

A test was recently run on one of the new boilers which was designed for a maximum capacity of 800,000 lb. of steam per hr. on which an output of 1,000,000 lb. of steam per hr. was maintained continuously for twelve hours with entirely stable furnace and water level conditions and with no signs of distress in any part of the equipment. A heat balance of this run is given in Table 2 indicating an efficiency of 86.5 per cent at an output of 25 per cent above the maximum guaranteed capacity, thus amply justifying our expectations for high sustained efficiencies. An output of 1,250,000 lb. per hr. has been maintained on one of these boilers for one hour and 15 minutes accompanied by a slight drop in efficiency.

TABLE II
HEAT BALANCE OF NO. 7 BOILER—OUTPUT 1,000,000 LB. PER HR.

	B.t.u.	Per cent
Loss due to moisture in coal	11	0.1
Hydrogen	453	3.0
Dry chimney gases	1,137	7.7
Combustible in refuse	73	0.5
Moisture in air	30	0.2
Radiation and unaccounted for	294	2.0
Total losses	1,998	13.5
Efficiency and heat to boiler	12,772	86.5
Total	14,770	100.0

With the exception of the first few months of operation, while initial adjustments of the equipment was being made, we have had no complaints due to either smoke or cinders from this station. The efficiency of the electrostatic and cyclone dust catching apparatus is such that we have been unable to locate any deposits of flue dust in the surrounding neighborhood.

Up to the time when this station was designed, practically all pulverized fuel furnaces had been very largely refractory lined and it was thought by designers that in spite of the high maintenance cost on such furnaces, a refractory lining was necessary to maintain stable fire conditions, particularly with low volatile coal. The furnaces in this station departed radically from previous designs in that they were completely water-cooled, in spite of the fact that our normal coal supply is of a low volatile character.

Considerable difficulty was experienced in the early stages of the station operation in maintaining stable firing conditions with the vertical burner system originally installed. After experimenting in various ways A. J. Wheeler, Jr., superintendent of the station, conceived and developed the idea that by applying a flame to the stream of coal immediately after its entrance to the furnace, combustion could be accelerated to a point where the heat radiated from the flame to the water-cooled walls did not reduce the flame temperature to a point where combustion was retarded.

Applying this principle, small auxiliary burners have been installed at right angles to each vertical burner, so disposed as to impinge on the stream of fuel leaving the vertical burner at a point slightly below its entrance into the furnace.

This method of burning coal has reduced the unburned carbon losses, increased the furnace capacity, eliminated all slag trouble, and made possible stable firing conditions at all rates of operation.

Ash Handling

The ashes from all the boilers are drawn into trenches running along both sides of the boiler room. They are sluiced along these trenches to a central ash pit into which the ashes collected from the cyclone separators and precipitators are also discharged. Centrifugal pumps remove these to a large concrete ash hopper on the dock from which they are loaded into scows by gantry cranes. Approximately 80 to 90 per cent of the ashes pass up through the boiler, the remaining 10 to 20 per cent being drawn from the ash pit.

Two types of cinder catchers are in use, cyclone separators and precipitators. A Davidson cyclone separator was installed on each of the first six boilers with satisfactory results. The only maintenance required has been the relining of the helix after two years of service. Two Cottrell precipitators have been installed on each of the three new boilers. They are giving excellent service, test runs showing efficiencies of 90 to 95 per cent.

Generating Equipment

The generating building will have accommodations for nine steam turbo generators of large capacity, three of which are already in operation. The first, of 60,000-kw., designated Unit No. 2 went into service November 19, 1926; the second, a 60,000-kw., Unit No. 1, on February 21, 1927; the third, a 160,000-kw. Unit, No. 4, on October 10, 1929. This unit which has a tandem compound turbine, using straight steam flow on the high pressure and double flow on the low pressure, has been operating very satisfactorily. To date no water rate tests have been made on this unit.

The generated potential is 11,400 volts, three phase, 25 cycles. All 25-cycle energy is transmitted at this voltage except for two 33-kv. feeders which tie through Lorimer Street substation with the Brooklyn Edison Company's Gold Street Generating Station and serve both as a supply to the Long Island Railroad and as a means of interchanging power between the generating stations. Three 15,000-kva. transformers step up the energy from the 60-cycle end of the frequency changer to 27,600 volts.

While it is expected that all future additions to this station will be for 60-cycle operation, the future

operating voltage has not as yet been determined.

Condensers

The condensers for the three units are all of the single-pass, surface type, those for Units No. 1 and 2 having 47,500 sq. ft. of surface and that for Unit No. 4, 90,000 sq. ft. of surface. Each condenser has two circulating water pumps which are all located in a pump room at the east end of the turbine room basement, adjacent to the water front. The water is pumped through cast iron pipes, 72 in. in diameter, embedded in the concrete mat, to the perspective condensers, the length of these pipes varying with the distance from the pumps. The last unit to be installed in the station will be approximately 1000 ft. away from the pumps. The overboard water from the condensers is discharged through individual 72-in. pipes to the river.

Units No. 1 and 2 each have two hot-well pumps while Unit No. 4 has three hot-well pumps. Steam jet vacuum pumps are used on all of the condensers.

The tubes are cleaned by shooting a mixture of sand and pulverized fuel ash in equal proportions, and water through the tubes by means of compressed air. The cleaning is done by sections whenever the turbines are shut down, usually on the 12:00 midnight to 8:00 a.m. watch or on Sundays.

Four stages of feed water heating is the practice at the East River Station, three by steam bled from the main units and one by the exhaust steam from the steam auxiliaries. Units No. 1 and 2 are bled from the 11th, 14th, and 18th stages and Unit No. 4 from the 13th, 17th, and 21st stages. The cycle of feed water heating is given in the accompanying typical heat balance for Unit No. 4. (Fig. 5)

Auxiliaries

Steam driven auxiliaries are used for the circulat-Tg w ater, boiler feed, and condensate pumping. fhe p rimary air, secondary air, and induced draft ans are also steam driven, thus providing a very even acceleration or deceleration of speed.

The non-essential auxiliaries, or those which may be shut down for short periods of time without affecting service, such as pumps for ash pit, house service, hot-well test, storage tanks, fire lines, dust precipitators, coal towers, and powdered fuel mills, are supplied from 2300-volt or 440-volt 25-cycle busses energized from house transformers on the main bus. These house busses also supply motors for ventilating fans for the main generator and frequency changers and other auxiliaries with similar duplex drives (steam and electric).

The transformers are supplied from different sections of the main bus and house busses are operated radially although provision has been made for parallel operation either as a solid bus or sectionalized by reactors.

A 125/250-volt d.c. house bus supplied from geared cross connected turbo generator units is provided for the operation of boiler fuel feed. The fuel feed motors of each boiler are supplied from a motor generator set connected to the d.c. house bus and provided with a Ward Leonard automatic control. The 250-volt bus also furnishes all building lighting and some small miscellaneous power. As a standby to the turbo-generator units there is a 2240-ampere-hour battery capable of maintaining full emergency load for one-half hour.

It was considered that the auxiliary drive system for a station such as this, designed to supply a large d.c. system, to be satisfactory from the standpoint of reliability, should be supplied from such sources that in the case of a break in any steam line, a shut-down of all the main generator units, a shut-down of any one auxiliary unit or the shut-down of the main bus would not interrupt the operation of the auxiliaries to more than one generating unit. It is recognized that these assumptions may not necessarily apply to other projects or to present day conditions in the territory served.

The careful study of all the systems in use at the time indicated that the following systems met the above requirements:

A. Steam turbines.

B. D.c. electric supply from the main bus with storage battery reserve.

C. A.c. electric supply from shaft alternators with main bus and house alternator reserve.

Designs and cost estimates were made for each of these three systems. These cost estimates indicated that the a.c. electric supply systems would cost 35 per cent more than steam turbines and the d.c. system 120 per cent more than steam turbines.

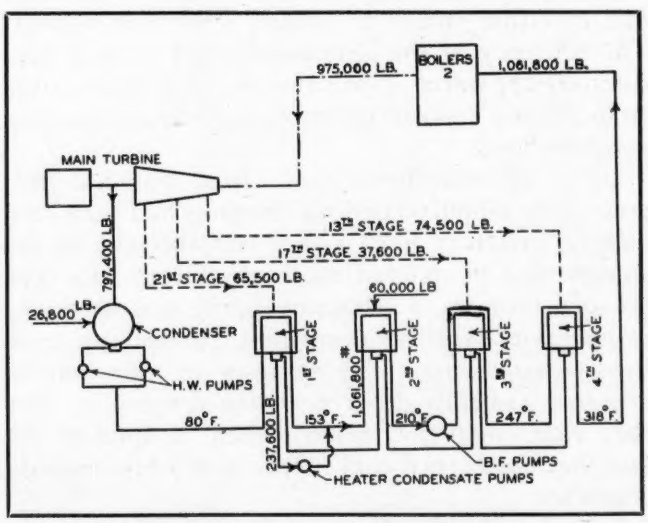


Fig. 5—Heat balance—Turbine Unit No. 4

(Electric supply estimates include a charge of $40.00 per kw. for electric generating capacity used for auxiliaries.) Heat balance calculations indicated that the additional fuel consumption of the steam drive system would if capitalized, reduce the above differential in the case of alternating current drive 2 per cent and with direct current, 3 per cent.

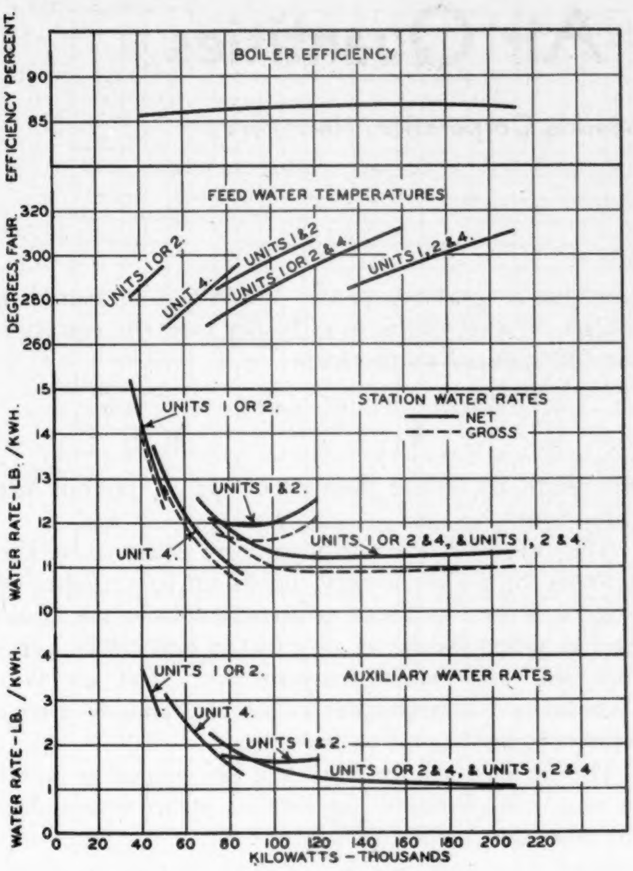


Fig. 6—Station performance data

Steam drive for these auxiliaries has been entirely satisfactory from the point of view of reliability. The steam consumption, however, is somewhat higher than the original calculations.

General Design Features of 1929 Extension

When it was decided to go ahead with the first extension of this station, it was found that turbine builders were prepared to supply single turbo generators, having a capacity of 160,000 kw. each, at a considerably lower cost per kw. than for the 60,000-kw. units in the original installation. It was then decided that in the extension of this station, the same number of units as originally planned would be installed, but that these units would have nearly three times the capacity of the original units. The manner in which this has been accomplished is illustrated by the following figures:

Turbo generators Nos. 1 and 2 (60,000-kw. capacity each) occupy 0.083 sq. ft. per kw. capacity, while turbo generator No. 4 (160,000-kw. capacity) occupies 0.0452 sq. ft. per kw. capacity. Boilers 1 to 6 (250,000 lb.-capacity each) occupy 9.2 sq. ft. and 1140 cu. ft. per 1000-lb. steam capacity. Boilers 7, 8 and 9 (1,000,000-lb. capacity each) occupy 4.5 sq. ft. and 625 cu. ft. per 1000 lb. steam capacity. Similarly the electrical galleries for generators No. 1 and No. 2 require 0.48 sq. ft. of floor area and 7.39 cu. ft. per kw. capacity, whereas similar equipment for generator No. 4 occupies 0.215 floor area and 3.92 cu. ft.

Station Operating Data

Fig. 6 shows in graphic form boiler efficiency, feed-water temperatures, total station and auxiliary water rates of this station when carrying loads from 35,000 to 210,000 kw. These curves are based on the station performance for the months of February and March 1930. The station heat rate is 15,000 B.t.u. per net kw-hr.

Details of Principal Equipment—1929 Extension

Boilers—Superheaters and Preheaters	
Type of boilers	Combustion Eng. Corp. Water cooled walls
Number installed	3
Heating surface per boiler, sq. ft.	60,706
Heating surface of water walls per boiler, sq. ft.	7,345
Furnace volume, cu. ft. above water screen	38,200
Boiler pressure, lb. gage	425
Superheat, deg. fahr.	271
Total steam temperature, deg. fahr.	725
Superheater, location	Superheater Company. In first pass
Superheating surface per boiler, sq. ft.	13,900
Air preheater, type	Combustion Eng. Corp. Stationary steel plate
Heating surface of air preheater per boiler, sq. ft.	82,721
Induced Draft Fans	
Induced draft fans	B. F. Sturtevant Co. 260,000 cu. ft. per min. at 17 in. static pressure
Number per boiler	2
Drive	Sturtevant turbine and gear. 1150 hp. turbine
Forced Draft Fans	
Forced draft fans	Sturtevant—125,000 cu. ft. per min. at 9 in. static pressure
Number per boiler	2
Drive	Sturtevant turbine and gear. 263 hp. turbine
Primary Air Fans	
Primary air fans	Sturtevant Co. 54,000 at 25 in. static pressure
Number	4 for three boilers
Drive	General Electric turbine and gear. 307 hp. turbine
Dust Collectors	
Dust collectors—type	Cottrell precipitator
Main Generating Units	
Capacity, kw.	General Electric Co. 160,000
Number	1
Generators	3 phase, 25 cycle, 11,400 volts
Speed rev. per min.	1,500
Exciter, type	Shaft driven
Capacity, exciter (kw.)	250 kw., 250 volts
Steam conditions at turbine throttle	375 lb. gage 725 deg. fahr. total temperature
Main Condensers	
Condenser, type	Ingersoll-Rand—Single pass
Tube surface, sq. ft.	90,000
Number per turbine	1

Editor's Note: Through the courtesy of the authors we publish herewith analysis of the coal used in the test of No. 7 Boiler at East River Station. A heat balance of this test is given in Table II which appears on page 43.

Proximate Analysis
(dry basis)

Volatile	21.5	*per cent*
Fixed carbon	72.4	" "
Ash	6.1	" "
B.t.u.	14,770	
Sulphur	1.4	" "

(Moisture in coal as fired—1 per cent)

How to Measure Air Quantities

By B. J. CROSS, Combustion Engineering Corporation, New York

AIR measurements may be made by means of the anemometer, the pitot tube or the orifice. The anemometer is used chiefly in heating and ventilation work where air is usually at low velocities. In power plant work where air is usually confined in ducts and is at higher velocities, the pitot tube or the orifice method is used.

The pitot tube is a device for measuring the kinetic head of a fluid. A common form is shown in Figure 1, (a). The opening facing the stream flow measures the total pressure—static plus dynamic. The small holes at right angles to the stream flow measure the static pressure. The difference is the dynamic head which is a measure of the velocity. The pitot tube has the advantage that it introduces practically no resistance to the flow of air in the duct. It has the disadvantage that it measures the velocity at only one point in the cross section of the duct. It is therefore, necessary to make an exploration of the duct with the tube and either average the results or attempt to locate the tube at a position of average velocity.

The orifice method of measuring air consists of placing an orifice restriction in the duct and measuring the difference in static head of the air across this orifice. The orifice may be a venturi or flow nozzle or it may be a thin plate having a circular orifice of a diameter from .2 to .7 of the diameter of the duct. These two types of orifice are shown in Figure 1 (b) and (c). The advantage of the venturi flow nozzle is that it has an area factor of practically 1. That is, the entire area of the orifice may be considered effective and the flow is determined by multiplying the area of the orifice by the velocity of the air. Such an orifice is, however, somewhat difficult to make as it must be either cast or spun. The thin plate orifice is easy to make and install. The full orifice area, however, is not effective and a factor (c) must be used to correct the actual area to the effective area. This correction is necessary because the air steam converges after it leaves the orifice and the velocity is measured at the constriction or "vena contracta." In Figure 1 (c) the orifice diameter is shown as D_1, and the diameter at the "vena contracta" is shown as D_3, which is usually about .6 of D_2.

The equation for velocity of air as determined from kinetic head, h is:

$$v = \sqrt{2gh}$$

v is velocity in feet per second; h the head in feet of the medium being measured, and g the acceleration due to gravity, 32.16. When h is measured in inches of water as is usually the case the equation may be reduced to the form:

$$v = 8.02\sqrt{\frac{h}{12} \times \frac{62.4}{d_g}} \text{ or } 8.02\sqrt{\frac{5.2\,h}{d_g}}$$

The term d_g is the density of air in pounds per cubic foot.

The curves of the accompanying chart show the velocity of air for kinetic heads up to 5 inches of water. They have been constructed from the equation as given for air at 29.9 inches barometric pressure and at various temperatures. The air was assumed to contain water vapor corresponding to a relative humidity of 30 per cent.

The flow of air in cubic feet per second is equal to v × CA, A being the area in square feet and C the constant of the instrument. For pitot tubes and venturi flow nozzles this constant may be taken as unity. For thin plate orifices the constant will vary from .6 to .7 according to the ratio of orifice diameter to duct diameter. The values of C for different ratios of D_2 the orifice diameter to D_1 the duct diameter are shown in the small insert chart on the opposite page. Thus, if with an orifice 12 inches in diameter in a pipe 24 inches in diameter the ratio =.5 and the constant C will be .63, this means that the area of the "vena contracta" is equal to the orifice area, .7854 square feet times .63. If the measured kinetic head is 3 inches of water the air velocity at 68 deg. fahr. would be:

$$v = 8.02\sqrt{\frac{3 \times 5.2}{.075}} = 115.7 \text{ feet per second.}$$

This result may be determined from the curves on the opposite page. The flow would be:

F = .63 x .7854 x 115.7 = 57.25 cubic feet per second.

Pitot tube readings and venturi nozzle readings may be reduced in the same way except that the orifice coefficient need not be used.

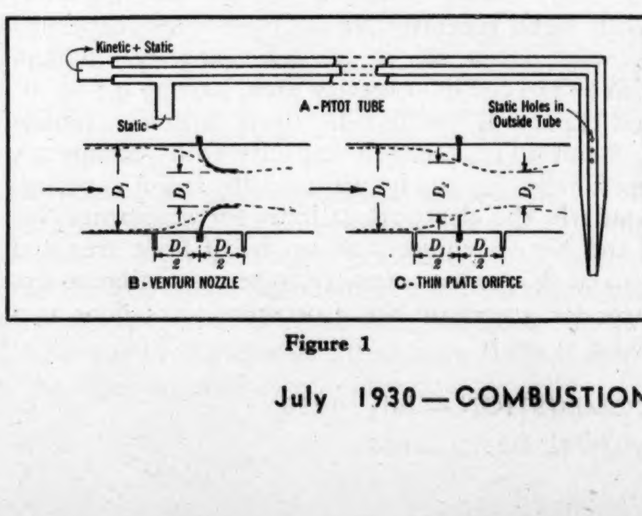


Figure 1

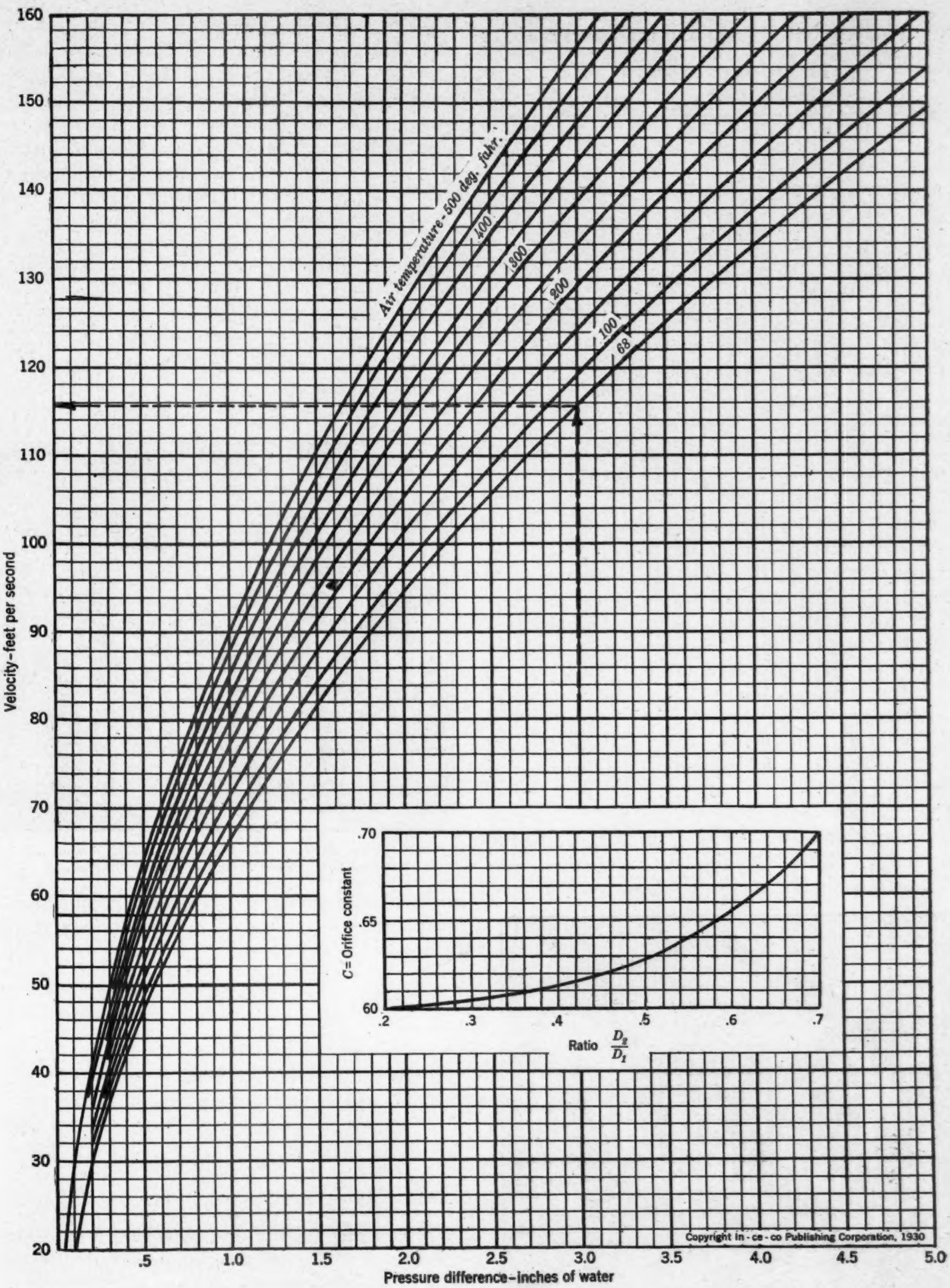
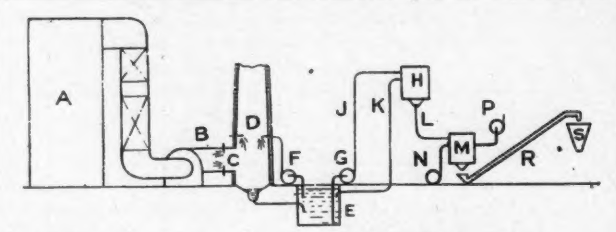


CHART FOR DETERMINING THE VELOCITY OF AIR BY MEANS OF ORIFICE OR PITOT TUBE READINGS

No. 12 of a series of charts for the graphical solution of steam plant problems

Description of New Steam Generators at Derby Station

(*Continued from page 38*)



A—Boiler
B—Main Flue
C—1st Set of Sprays
D—2nd Set of Sprays
E—Chimney Washing Sump
F—Spray Supply Pump
G—Slurry Pump
H—Hardinge Thickener
J—Slurry Discharge to Thickener
K—Water Return to Sump
L—Slurry Discharge to Filter
M—Rovac Filter
N—Air Compressor
P—Air Extraction Pump
R—Elevator
S—Storage Hopper

Fig. 5—Diagram showing travel of gases and arrangement of gas washing apparatus

the tubes, increasing the amount of heating surface. Feed water enters the bottom and flows progressively upwards opposite to the direction of travel of the flue gases, giving an approximately uniform temperature between the gases and water. The elements take their supply of feed water from a common header, but they discharge independently to the boiler drum, being connected to it by a series of plain tubes.

Air preheaters are of the Usco plate type and are located on the main floor directly under the economizers.

The flue gases on leaving the air preheaters pass to shunt-suction dust collectors, discharging to the main flue which leads to the flue gas washing system, illustrated in Fig. 5. The latter system is located

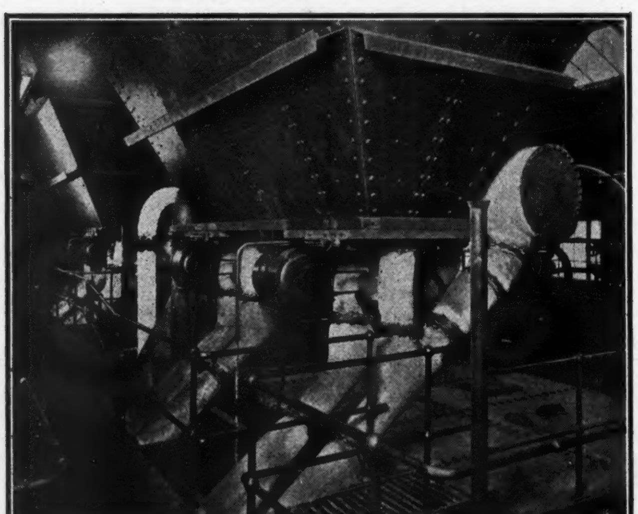


Fig. 6—View showing pulverized coal bins and feeders for new units

in the base of the stack, which is divided into two parts by a brick work partition extending to a considerable height. The gases from the two original boilers enter on one side of this partition and the gases from the three newer units on the other. On each side of the dividing wall four sprays are fitted, supplied with water under pressure and discharging downwards against the flow of gases. These sprays effectively remove any dust or grit remaining in the gases and carry it down to a deep sump at the base of the stack from which an underground drain continuously carries away the sludge. There is now in the course of construction a continuous treatment plant which will handle all the sludge from the stacks separating the water from the ash and returning the water to the supply tank.

The following table indicates the increase in electrical output at the Derby Station from the year 1903 up to the present, and the marked reduction in coal consumption per kw. hr. over this period. The present average coal consumption of 2.21 lb.

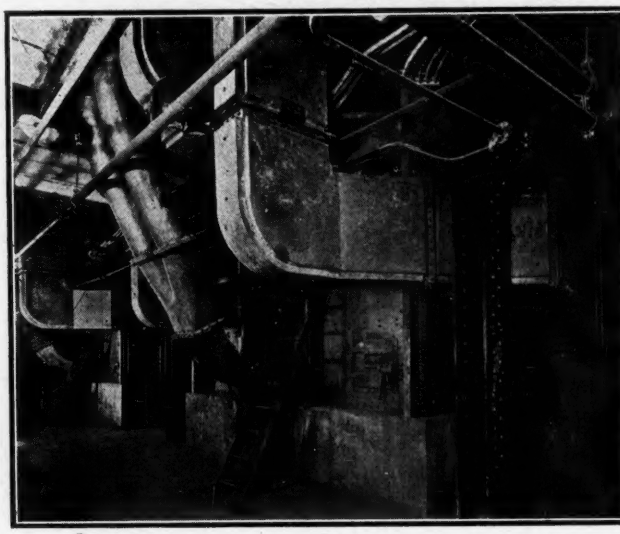


Fig. 7—View of lower part of steam generators showing air and fuel supply lines for volcano burners

per kw. hr. is considered very good, as an extremely cheap and low grade coal is used, averaging only about 9,000 B.t.u. per lb.

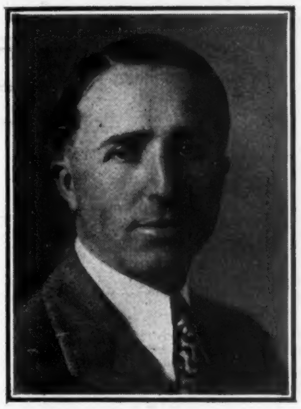
Year	Total kw.-hr sold	Lb. of coal consumed per kw.-hr.
1903—1904	1,490,611	10.00
1909—1910	4,660,247	7.05
1914—1915	7,941,609	5.12
1916—1917	12,161,151	4.16
1920—1921	19,435,989	3.07
1924—1925	25,126,816	2.22
1928—1929	33,320,044	2.21

The contract for the new extension was awarded in February, 1929, and erection was started in June, 1929. The work of installation was completed very rapidly, permitting preliminary trials the latter part of November and commercial operation in December, although as pointed out previously the extension was not officially opened until March. While complete operating results are not as yet available for publication, the results thus far secured indicate that all guarantees will be fully met.

NEWS

Pertinent Items of Men and Affairs

Floyd B. Hobart Joins Staff Of Battelle Memorial Institute



FLOYD B. HOBART

THE Trustees of Battelle Memorial Institute, Columbus, Ohio, announce the appointment of Floyd B. Hobart as Fuel Chemist. Mr. Hobart joins the staff with Ralph A. Sherman, Fuel Engineer, to work under the direction of Clyde E. Williams, Assistant Director. This group forms the nucleus of an organization within the Institute devoted to research problems in fuels.

Mr. Hobart is a graduate in chemical engineering from the University of Illinois where he later taught gas and fuel analysis while obtaining his Master's Degree in industrial chemistry. From 1921 to 1927 Mr. Hobart was on the staff of the Engineering Experiment Station at the University of Illinois as research assistant in chemical engineering, where he worked with Dr. S. W. Parr on the constitution, weathering, and carbonization of coal.

From 1927 to 1929 Mr. Hobart was in charge of the semi-plant scale experiments on the Parr process of carbonization for the Urbana Coke Company.

Mr. Hobart comes to Battelle Memorial Institute from the Atlantic Refining Company where he has been chemical engineer in standardization work.

Business and Engineering Administration Department for M.I.T.

As a preparation for managerial and executive responsibility in industry, a business training with an engineering background is to be provided by a new department of undergraduate and graduate instruction at Massachusetts Institute of Technology, Cambridge, Mass.

The present course in engineering administration which was started in 1914, will form the nucleus of the new Department of Business and Engineering Administration, which will be established this autumn. This year 298 students were enrolled in the present course, and the new department was created in recognition of the growing demand for technically trained men as business executives.

Delegates to World Power Conference Announced

The names of the delegates appointed to represent the national engineering societies of the United States at the World Power Conference to be held in Berlin, Germany, June 16 to 25, have been announced by O. C. Merrill, chairman of the American Committee for the Conference, as follows:

American Society of Civil Engineers: Arthur P. Davis, L. F. Harza, Ely C. Hutchinson, George A. Orrok, David B. Rushmore, Charles W. Spooner, and W. F. Uhl, Boston.

American Society of Mechanical Engineers: Dr. Robert Sibley, Dean Arthur M. Greene, Jr., Prof. A. G. Christie, D. Robert Yarnall, W. L. Abbott, Francis Hodgkinson, George A. Orrok, Charles E. Gorton, Clifford B. Le Page, Louis C. Marburg, W. S. Monroe, Col. Theodore A. Peck, Dr. H. C. Dickinson, L. F. Harza, Ely C. Hutchinson, Carl C. Thomas, Victor J. Azbe, and E. N. Trump.

American Institute of Electrical Engineers: Dr. Arthur E. Kennelly, L. T. Robinson, Dr. Clayton H. Sharp, L. W. W. Morrow, and Irving E. Moultrop.

American Institute of Mining and Metallurgical Engineers: Scott Turner, David B. Rushmore, Gustav Egloff, and Dr. H. Foster Bain.

•

The Edward Valve & Manufacturing Company, East Chicago, Indiana, has appointed Riffe & Thomas, Inc., Charleston, West Virginia, as its district representative to succeed the W. A. Ross Company, also of Charleston.

•

The Stephens-Adamson Manufacturing Company, Aurora, Ill., engineers and manufacturers of conveying and elevating machinery, announce the removal of their New York sales and engineering office to 50 Church Street, Room 1360.

•

The Superheater Company has moved its general offices to new quarters in the Lincoln Building, 60 East 42nd Street, New York.

•

The B. F. Sturtevant Company, Hyde Park, Boston, Mass., manufacturers of blowers, heaters and ventilators, announces the removal of its Minneapolis branch office from 1024 Metropolitan Life Building to 874-875 Northwestern Bank Building. P. A. Dwyer will remain in charge.

•

Blaw-Knox Company, Pittsburgh, Pa., announces the following changes in its Birmingham office, Brown-Marx Building, Birmingham, Alabama.

William E. Balliet succeeds P. V. Kelly as district manager. Joseph Riley has been appointed assistant district manager.

Hot Lime Soda Phosphate Treatment of Feed Water for High Pressure Boilers

(*Continued from page 23*)

phosphate feed not only prevents the formation of a silicate scale, but at the same time reduces the boiler alkalinity.

It is thus quite apparent that the lime and soda hot process is the most logical for most boiler feed water supplies, due to its inherent characteristics of flexibility of chemical control and the resulting cleanliness of boiler surfaces.

Welded Vessel Tested to 10,000 lb.

Smithwelded chrome-vanadium vessel subjected to pressures up to 10,000 lb. per sq. in.

The most severe tests to which a welded vessel has ever been subjected reaching pressure of 10,000 pounds per square inch were recently completed at the plant of the A. O. Smith Corporation in Milwaukee.

The vessel tested is a reaction chamber built of Chrome-Vanadium steel by SMITHWelding for 5,000 pounds per square inch working pressure in a chemical process. Walls are three and one-half inches thick. The vessel is thirty-three feet long with twenty-six inch I. D.

Following routine repeated stress tests and hammer tests at 8,000 pounds the pressure in the vessel was raised to 10,000 pounds per square inch and the entire vessel was carefully examined. As shown in the accompanying illustration there was no scaling of the lime wash. Careful measurement and liquid volume readings showed that the vessel took no set or permanent distortion from the extremely high test pressures.

The vessel was shipped for installation on the same night that the tests were concluded.

The Thermal Properties of Gases

(*Continued from page 35*)

solute zero of temperature the entropy may become zero, and does so become in the case of a perfect crystalline substance." The entropies of several elemental gases per gram-molecule as given by Lewis and Randall for the temperature of 25 cent. and one atmosphere pressure, are:

Monatomic gases,

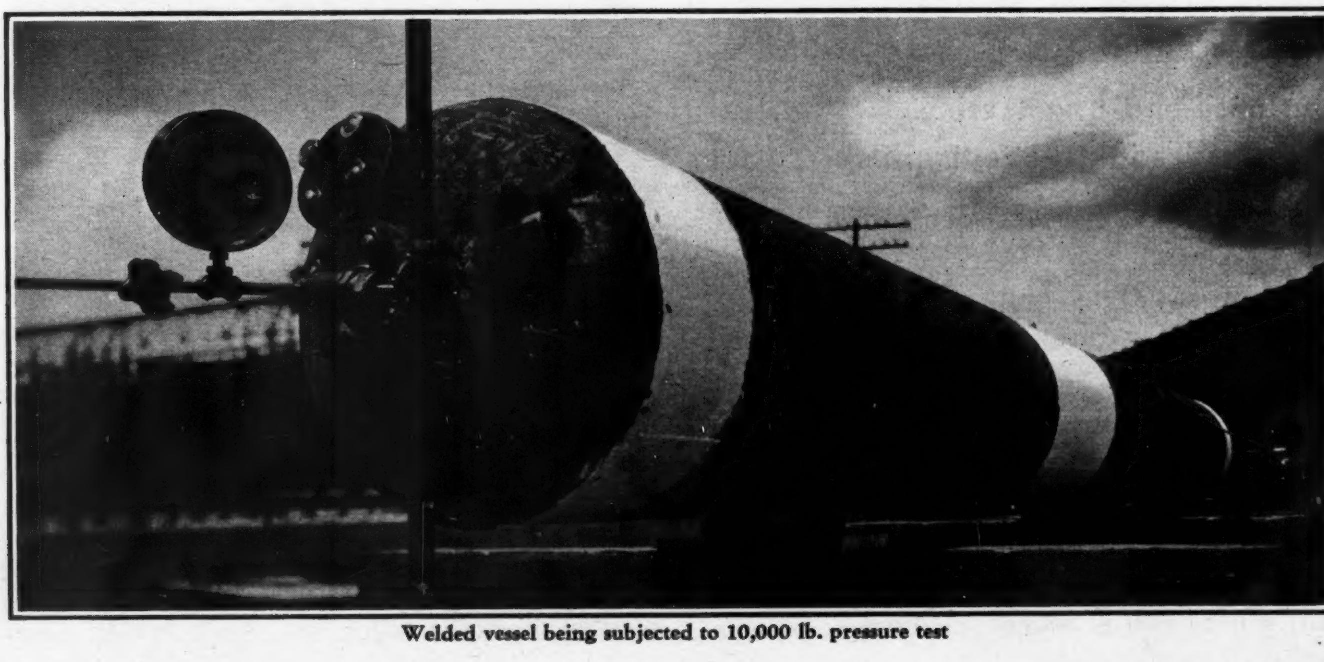
Argon	36.7	cal. per deg. cent.
Helium	29.8	" " " "
Mercury	41.5	" " " "

Diatomic gases,

Hydrogen	29.4	cal. per deg. cent.
Oxygen	48.0	" " " "
Nitrogen	45.6	" " " "

References

Partington and Shilling's book on the Specific Heats of Gases discusses the various experiments which have been made to determine the specific heats of gases. The article on Specific Heats of Gases in Glazebrook's Dictionary of Physics is also of interest as well as Bulletin No. 139 of the University of Illinois Engineering Experiment Station by Goodenough and Felbeck entitled, "An Investigation of the Maximum Temperatures and Pressures Attainable in the Combustion of Gaseous and Liquid Fuels." U. S. Bureau of Standards Bulletin No. 136, On the Definition of the Ideal Gas supplements the discussion in the present article. For the thermodynamic properties of oxygen and nitrogen below atmospheric temperatures, see Technical Paper No. 424 of the U. S. Bureau of Mines. Lewis and Randall's book on Thermodynamics contains a thorough discussion of the third law of thermodynamics.



Welded vessel being subjected to 10,000 lb. pressure test

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured from In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

Strength of Materials

By S. Timoshenko

THIS book is divided into two volumes. Volume 1, reviewed here, is devoted to elementary theory and problems.

In this volume attention has been given to simplifying all derivations as much as possible so that a student with the usual preparation in mathematics will be able to read it without difficulty. For example in deriving the theory of the deflection curve, the *area moment method* is extensively used. In this manner, a considerable simplification is made in deriving the deflections of beams for various loading and supporting conditions. In discussing statically indeterminate systems, the *method of superposition* is applied, which proves very useful in treating such problems as continuous beams and frames. For explaining combined stresses and deriving principal stresses, use is made of the *Mohr's circle*, which represents a substantial simplification in the presentation of this portion of the theory.

Using these methods of simplifying the presentation, the author has been able to condense the material and to discuss some problems of a more advanced character. For example, in discussing torsion, the twist of rectangular bars and of rolled sections, such as angles, channels, and I beams, is considered. The deformation and stress in helical springs are discussed in detail. In the theory of bending, the case of non-symmetrical cross sections is discussed, the *center of twist* is defined and explained, and the effect of shearing force on the deflection of beams is considered. The general theory of the bending of beams, the materials of which do not follow Hook's law, is given and is applied in the bending of beams beyond the yielding point. The bending of reinforced concrete beams is given consideration. In discussing combinations of direct and bending stress, the effect of deflections on the bending moment is considered, and the limitations of the method of superposition is explained. In treating combined bending and torsion, the cases of rectangular and elliptical cross sections are discussed, and applications in the design of crankshafts are given. Considerable space in the book is devoted to methods for solving elasticity problems based on the consideration of the strain energy of elastic bodies. These methods are applied in discussing statically indeterminate systems. The stresses produced by impact are also discussed. All these problems of a more advanced character are printed in small type, and may be omitted during the first reading of the book.

The book is illustrated with a number of problems to which solutions are presented. In many cases, the problems are chosen so as to widen the field covered by the text and to illustrate the application of the theory in the solution of design problems.

This book is 6¼ by 9¼ overall and contains 370 pages. Price $3.50.

Elements of Steam and Gas Power Engineering

By Potter and Calderwood

THIS book has been prepared primarily as a textbook for students in engineering schools and colleges in order to familiarize them with power-plant equipment before they take up the more abstract study of thermodynamics and design. In the third edition, which is here reviewed, many of the chapters have been largely rewritten and new material of a theoretical nature has been added. The subject matter is so prepared that it should prove of considerable value to those who are responsible for the operation of steam or internal-combustion engine power plants. Illustrative problems will be found at the close of each chapter.

The main portion of the book is divided into three parts. The first part takes up the subject of steam power and includes fuels, combustion, theory of steam generation, boiler accessories, steam engines, steam turbines, auxiliaries for steam engines and turbines, and the testing of steam-power equipment. The second part is devoted to gas power and includes a study of the internal-combustion engine, fuels for internal-combustion engines, gas producers, and the various auxiliaries found in connection with internal-combustion engine power plants. The last portion of the book treats of the application of steam and gas power to locomotives, automobiles, trucks and tractors.

The method followed in each chapter is to give: first, the fundamental principles underlying the particular phase of equipment under consideration; second, the structural details; third, auxiliary parts; fourth, operation and management of the equipment.

The book is 5¾ by 8½ overall and contains 370 pages. Price $2.75.

NEW EQUIPMENT

of interest to steam plant Engineers

High Pressure Gage Glass

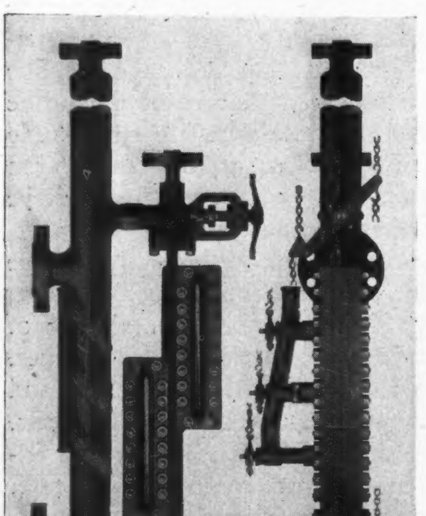
An important development in high pressure gage glasses and water columns has been announced by the Diamond Power Specialty Corporation, Detroit, Michigan. A salient feature of this new design is the "loose window" construction, so named from the ingenious design which makes it unnecessary to clamp the glass in order to obtain a seal against the steam pressure.

As boiler pressures have increased, experience has indicated that satisfactory service cannot be obtained from tubular water gage glasses, and with boilers operating at pressures above 350 lb., the life of such glasses is usually limited to a few weeks.

The short life of the glass is due to several different reasons; namely, the solvent action of boiler water at high pressure and temperature, the strains set up in the glass due to the effort to keep the glass tightly packed against the high pressures, and the inability of the glass to withstand the high steam pressures.

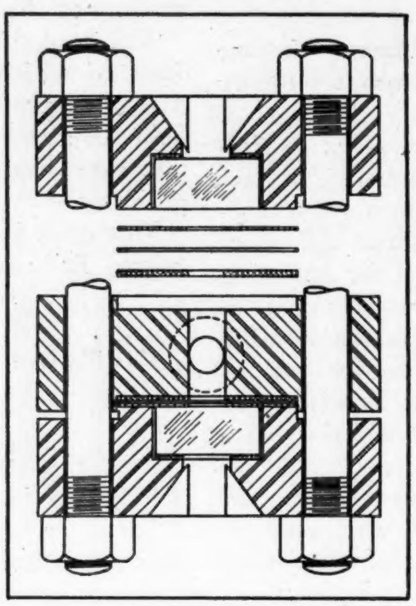
Pure feed water at a pressure of 350 lb. and upward has a rapid chemical action on glass, and even were the strength unimpaired, it is quite difficult to avoid breaking the tubular type of glasses when packing them for pressures of 600 lb. and upward.

Double flat glass types protected on the water side by mica have been developed for



pressures above 350 lb. For higher pressures, however, it has been found that tightening the gage body directly against the glass in order to produce a water and steam tight joint, sets up strains that crack the glass, sometimes even before it is put into service.

The Diamond High Pressure Gage Glass clamping of the glass is avoided. A clear sheet of mica is clamped under each glass frame and forms what might be called a diaphragm or drum-head. The glass is virtu-



ally loose, being cushioned against the mica and supporting it.

was developed to overcome this defect. The

This unique construction leaves the glass entirely free from clamping strains, and protected also, from damage that might otherwise result from expansion and contraction. As a consequence, longer glasses affording greater length of vision are obtainable.

The glass is never subjected to higher pressure than the steam pressure itself. Gages of this design can therefore be used on boilers operating under extremely high pressures as it is not necessary to subject the glass to dangerous pressures.

The gage valve bodies are of forged steel. Seats are renewable and made of heat treated stainless steel. The self aligning valve discs are of monel metal. Valve stems are of the same metal, and special threads, external to the valve body, assure quick opening. Design of valves provides for quick renewal of any part. Gage cocks have renewable seats, discs, and stems and follow the same general design as is used in the gage valves.

This new development provides a rugged and reliable gage glass and water column which is particularly adapted to high steam pressures.

Plastic Stack Lining

Every year millions of dollars are wasted through the rusting, deterioration and disintegration of steel structures. Much of this loss could be prevented by the timely use of comparatively simple and inexpensive methods which extensive research and manufacturing experience have combined to make available.

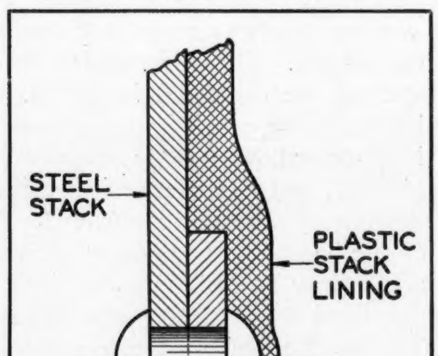
One of the recent developments in this field which is applicable to power plant installations is CE-CO Stack Lining, a plastic compound developed by Cheesman - Elliot Company, 639 Kent Avenue, Brooklyn, N. Y., and designed to supplant the use of costly brick lining in stacks.

The principal claims for this composition are that, under the usual operating conditions, it saves construction cost by eliminating the necessity of using brick lining, by saving about 9 in. in the exterior diameter of the stack, and reducing the weight of the lining approximately 38 pounds per square foot. The result is that about two-thirds of the cost of brick lining is saved by the use of this new plastic lining, and further saving is effected by economies in the structural design of the foundation for supporting the stack, due to the comparatively light weight of the lining.

It is well known that brick lining does not make a complete contact with the interior surfaces of stacks and this allows fumes, gases and moisture to attack the metal through cracks in the mortar and other defects, where their action may go on unobserved and serious structural weakening take place. These disadvantages are overcome by the use of the new stack lining, which is a material of putty-like consistency which requires no heating or complicated mixing for application. The composition adheres directly to the metal and forms a continuous, jointless lining from the top to the bottom of the stack. By reason of its intimate contact with the entire surface, the plastic lining gives greater protection against corrosion than is realized in the case of brick linings. It can be easily and quickly applied with a trowel or other suitable device and dries throughout to a dense, tough, adhesive and cohesive mass which is not disrupted by the expansion, contraction and flexing of the metal.

The stack lining is recommended for use in steel stacks, particularly those designed for power plants which have generally been lined with fire brick, to prevent the corrosive action of moisture and flue gases, and the corrosive action of cinders and other solid particles on the steel shell.

The grinding action of cinders and dust particles traveling up the stack is a trouble-



some factor which this lining successfully combats due to its tough and dense nature.

This lining may also be used before installing brick lining, where the latter is desired for insulation, for facing new or old brick linings to exclude gases and acids from the masonry and for protecting cinder catchers, flues and other construction from abrasion.

NEW CATALOGS AND BULLETINS

Any of the following literature will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Ash Conveyor

A new catalog presents the Steamatic Ash Conveyor System. This development is a pneumatic pipe line conveyor in which a high velocity air flow is produced by a very efficient steam ejector placed at the discharge end of the line. This ejector consists of a group of small Monel metal steam nozzles directed in the line of air flow, yet fully protected from abrasion from the material conveyed. The principal advantages of the location of the ejector at the discharge end and of the use of several small jets instead of one large jet are (1) Lower steam consumption, (2) Greater capacity, (3) Lower maintenance, (4) Quieter operation. Typical layouts are included. 16 pages and cover, 8½ x 11—United Conveyor Corporation, Old Colony Building, Chicago.

Boiler Baffles

A bulletin entitled "How BECO Baffles Modernize Old and New Water Tube Boilers" has just been issued. Numerous illustrations show how to baffle correctly all types of water tube boilers—horizontal and bent tube. Actual charts are included to show fuel savings effected by the use of BECO baffles. Savings as high as $39,000 per boiler are estimated by modernizing the old boiler, keeping it out of the junk heap, and converting it into an efficient boiler. It is claimed by the builders that in many instances old boilers, when equipped with correct baffles are made more efficient than new boilers which are improperly baffled, and that the efficiency of new boilers is commonly improved by equipping them with this modern type of boiler baffle wall. 4 pages, 8½ x 11—Boiler Engineering Company, 24 Commerce Street, Newark, N. J.

Centrifugal Pump

"The Centrifugal Pump," compiled for Goulds by F. G. Switzer, Professor of Hydraulic Engineering, Cornell University, is in every respect a practical handbook of data valuable to technical student, trained engineer and pump operator alike.

One of the most interesting chapters in the book is that on testing, where the reader is taken through a modern testing laboratory and shown, step by step, how centrifugal pumps are inspected and put in perfect operating condition before they leave the factory. The user of pumps will also find much of interest in the many valuable curve charts the book contains. 48 pages, and cover, 8½ x 11—Goulds Pumps, Inc., Seneca Falls, New York.

Draft Gages

Ellison Draft Gages of the tube type are shown in a new Bulletin 9-A. Both inclined and vertical gages, with single or multiple tubes, are included. A wide range of scales is available and the gages may be adapted for plus, minus or differential readings. Numerous illustrations show details of design of the different types of gages and of fittings and connections which are useful in mounting gages and taking draft measurements. List prices are quoted. 12 pages, 8½ x 11—Ellison Draft Gage Company, 214 West Kinzie Street, Chicago, Illinois.

Flue Gas Analyzers

The new model Hays Flue Gas Analyzer is presented in Catalog TSE-30. The steelwool surface method of gas absorption gives quick results. A CO_2 reading can be made in 30 seconds and complete analysis for CO_2, O_2 and CO in four minutes. The chemical containers are of molded hard rubber instead of glass. Being opaque they protect the chemical from deterioration by light. The case is of corrosion resistant metal, spot welded and finished in black Duco. All parts are readily accessible and may be cleaned in two minutes. The catalog includes interesting sections on combustion and gas analysis. 20 pages, 8½ x 11—The Hays Corporation, East 8th Street, Michigan City, Indiana.

Multiple Retort Stoker

Detroit Multiple Retort Stokers are illustrated and described in a new catalog just issued by the manufacturers. The principle of the level fuel bed which prevents avalanching, the double control of the flow of fuel and its distribution in each retort, the graduated distribution of air, the use of side wall wind boxes, the power operated dump for large stokers and other features are all illustrated in detail. The catalog illustrates the wide choice of setting arrangements with the simplicity of removal of ash from the stokers due to the level fuel bed with ash reaching the dumps at the same level that the coal enters the furnace. 32 pages and cover, 8½ x 11—Detroit Stoker Company, General Motors Building, Detroit, Michigan.

Oil Gas System

Natural gas is recognized as an ideal industrial fuel. The question of continuous service, under conditions of varying supply and demand, is perhaps the greatest deterrent to the still more universal adoption of gas fuel. Storage holders are economically limited to meeting peak loads and emergencies for a matter of hours only and the rational means of insuring continued gas supply is auxiliary gas manufacturing equipment, to supplement the natural gas when it is low and to replace it if it should fail. The Dayton-Faber system described in a new bulletin No. 4 has proved well adapted to this service. Light fuel oil is atomized and mixed with preheated air, partial combustion and cracking takes place and a fixed gas of any desired heating value from 300 to 500 B.t.u. results. The operation is simple and continuous, no steam is required, and the thermal efficiency of the process is from 70 to 80 per cent. 16 pages, 8½ x 11—General Oil Gas Corporation, 24 Broad Street, New York.

Plastic Refractory Material

"Hytempite in the Power Plant" is the title of a new and comprehensive catalog which illustrates and describes the application of "Hytempite," a plastic refractory material, for bonding fire brick and for kindred uses. Hytempite forms a lasting bond, air sets at normal room temperatures and retains its strength up to temperatures at which the best quality of firebrick soften or fail. It can be used as a binder wherever fire clay brick, silica brick, tile or granular refractories are used. Numerous illustrations show the many uses of this material in the power plant. 24 pages, 8½ x 11—Quigley Furnace Specialties Company, 56 West 45th St., New York.

Pressure Regulation

Bulletin S-22-A describes the construction and application of the S-C Master Control which is offered as a highly developed, yet simple mechanism, for obtaining very accurate pressure regulation. This regulator operates on the principle of amplifying small pressure variations into large variations so that a tremendous working pressure is developed. Apparatus is offered for pressures up to 1,350 lb. per sq. in. 24 pages, 8½ x 11—The Swartwout Company, 18511 Euclid Avenue, Cleveland, Ohio.

Pressure Regulator

The Brooke Constant pressure regulator is shown and described in Bulletin V2. This regulator is designed to maintain a constant pressure of a liquid or a gas by the operation of a valve or damper whose action is almost instantaneous on the pressure to be held constant. Essentially, the regulator consists of a diaphragm, a magnifying connection which translates a very small diaphragm movement into a movement which is sufficient to close the electric contacts, a small universal-type electric motor and a unique type of compensating dash pot. The regulator is sensitive to very small pressure changes. 8 pages, 8½ x 11—Brooke Engineering Company, 1321 Arch St., Philadelphia, Pa.

Small Stoker

The Modern Coal Burner is a small stoker of the underfeed type designed for apartment buildings, schools, institutions, hotels, office buildings and small factories. It is available in a range of sizes and may be applied to any type of steam or hot water boiler developing from 15 to 200 hp. The coal is fed from the hopper at the boiler front into the retort in the furnace by means of a screw which is driven by an electric motor. A separate, motor-driven fan supplies air for combustion. Simple and reliable, electric automatic control of coal feed and air supply, is provided. A new folder describes the stoker in detail and illustrates the construction and application. 8 pages, 8½ x 11—Modern Coal Burner Company, 3733 North Lincoln Ave., Chicago, Ill.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION
200 Madison Ave., New York

American Progress in Coal Firing of Boiler Furnaces

(Continued from page 30)

enabled owners to diagnose their own petty difficulties and to make minor adjustments without calling for dealer or factory service."

The progress of the small stoker industry in the comparatively brief period of its existence is nothing short of remarkable, and its outlook for the future appears bright indeed. This situation is well summed up in the following paragraphs which conclude Mr. Banfield's paper and the symposium:

"In the brief period of six years, the small stoker industry has grown from a few scattered installations in greenhouses to the rather impressive total of more than 30,000 installations in hundreds of different kinds of establishments. From the one pioneer manufacturer in 1924, the field of operation has expanded to include more than fifty manufacturers. From an uncertain experiment, the small coal stoker has become an accepted and recognized part of the modern boiler room in industries and in homes. Today it may be said that this new industry has cast off its swaddling clothes and stands ready to contend for its place in the sun.

"The future expansion of the small stoker industry is limited only by the number of dealers and salesmen it can develop. The thousands of installations which have already been made are nothing compared with the hundreds of thousands of visible prospects. If the remarkable progress made in the past six years can serve as any indication of future growth, it is certain the small stoker will exert an astounding influence in American economic and social life.

"For one thing, it will reinstate coal as the universal fuel, and will conserve our diminishing American petroleum resources for use in refined form in meeting the rapidly increasing demands of internal combustion engines on land, at sea, and in the air. Further, universal utilization of stokers will eliminate countless hours of unproductive labor and will save many millions of dollars while enhancing the comfort and physical well-being of mankind.

"To visualize the vast horizon of opportunity in this field, one has but to consider that in the United States there are more than twenty million homes; nearly three hundred thousand manufacturing establishments; more than two hundred and fifty thousand schools; approximately one hundred and fifty thousand office buildings and apartment houses, not to mention the thousands of greenhouses, laundries, and dairies. In truth, it may be said that the adaptation of mechanical stoking devices to boilers of less than 200 hp. has been the most outstanding development of recent years in the American progress in coal firing of boiler furnaces."

BOOKS

of Current Interest to Engineers

PIPING HAND BOOK

By J. H. Walker and S. Crocker 763 pages—Price $5.00

This book represents a very comprehensive compilation of reference information on piping. The following list of chapter headings indicates its scope: Definitions, Formulas and Tables; Fluids—Properties of Fluids; Metallurgy of Piping Materials; Pipe, Valves and Fittings; Heat Insulation; Hangers and Supports; Expansion and Flexibility; Steam Power Plant Piping; Building Heating Systems; Plumbing Systems; Underground Steam Piping; Water-Supply Piping; Fire-Protection Piping; Oil Piping; Gas Piping. The data presented on each phase of the subject is well arranged and complete. Numerous examples are given to facilitate the use of the information and formulas presented.

MECHANICAL EQUIPMENT OF BUILDINGS

By L.A.Harding and A.C.Willard, Vol.I

Price $10.00 964 pages

As a reference book this volume is of great value to those who have occasion to refer to the vast variety of technical matters involved in heating and ventilating. The mathematical and physical aspects of steam, water, air and fuels are thoroughly discussed, and examples are used to illustrate a variety of typical problems. The methods and apparatus for all the modern forms of heating are adequately treated.

ELECTRIC SYSTEM HANDBOOK

By C. H. Sanderson

Price $5.00 1167 pages

This book answers the increasing demand for a handbook which will tell the story of the electric system as a whole, in logical sequence and in a simple form readily understandable by everyone whether he possess a technical education or not. It gives complete and authoritative information on every phase of the work—the fundamentals of electricity; generating, transforming and auxiliary equipment; central and sub-stations; power lines; design, construction, operation, repair and inspection. Higher mathematics is entirely omitted and all technical expressions are fully explained.

THE THEORY OF HEAT

By Thomas Preston

Price $8.50 836 pages

This book is not a text-book for the class room, but an exposition in considerable detail of the theory of heat. The subject matter constitutes a most carefully compiled reference work of the greatest value to everyone to whom a complete knowledge of the theory of heat is necessary or desirable.

EVAPORATING, CONDENSING AND COOLING APPARATUS

By E. Hausbrand and A. C. Wright
Revised by Basil Heastie

Price $8.00 468 pages

This book is a very complete discussion of the calculations involved in connection with the equipment covered by its title. It goes exhaustively into the scientific side of the subject, and the reader will find the most minute and detailed items of operating functions thoroughly analyzed and explained. The numerous tables of the various quantities involved will be extremely useful to the designer or research engineer. The present volume is the fourth edition which has been revised so as to be thoroughly up to date.

HEAT TRANSMISSION IN BOILERS, CONDENSERS AND EVAPORATORS

By R. Royds

Price $6.00 310 pages

This book demonstrates the practical application of the laws of heat transmission in commercial equipment. The heat efficiency of various designs of boilers, condensers and evaporators is thoroughly analyzed and comparisons are made between the various types. For the engineer concerned with problems involving design and use of such equipment, this should be a valuable book.

BOILER FEED WATER PURIFICATION

By S. T. Powell

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A presentation of such basic facts concerning feed-water treatment as may assist the designing engineer in the selection of the appropriate type of treatment and may aid the operating engineer in controlling the system most efficiently.

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E. H. Whitlock Heads Smoke-Abatement Work in New York

The appointment of Colonel Elliott H. Whitlock as research professor of mechanical engineering to deal exclusively with the problem of smoke abatement in the New York metropolitan area, was announced by Dr. Harvey N. Davis, president of Stevens Institute of Technology, June 6.

The appointment was made possible by a gift to the college from a source not disclosed, of $40,000 to cover the costs of an anti-smoke campaign for the first two years.

Dr. Davis, one of the organizers of the New York-New Jersey Smoke Abatement Board and a member of that board, said the methods used by Colonel Whitlock in Cleveland, where he is smoke commissioner, have been regarded as the best in any American city.

Use of Stokers for Brick Kilns

The possibility of improving the ware and of reducing the costs of burning bricks in the down-draft round type of brick kiln is of great interest to all manufacturers using that type of kiln, of which there are many thousands in the country, the United States Bureau of Mines, Department of Commerce, points out. By far the greater number of such kilns use coal, with 6 to 10 hand fired furnaces per kiln and natural draft, which limits the control possible. The use of stokers means an increased investment which must be more than offset by an increase in the percentage of high-grade brick, better uniformity of the ware, a reduced fuel consumption, a shorter time of burning, and possibly a reduction in labor costs.

While some attempts have been made to replace hand-firing by stokers, but without much success; these trial installations have been limited, and have not attempted to take advantage of their full possibilities. A more intensive study of the application of a stoker to a round kiln is one of the problems of the joint investigation being conducted at Roseville, Ohio, by the Pittsburgh Experiment Station of the United States Bureau of Mines, and the Ohio State Engineering Experiment Station. The primary object at present is to determine how much improvement in ware and saving in fuel can result from a more uniform distribution and closer control of heat. The first installation has one stoker which fires two kilns alternately. The hot gases are conducted to the center of each kiln to obtain uniform distribution; forced draft for the stoker permits control of the pressure in the kiln and of it being positive.

The stoker has enabled the operators to control closely the rate of heating, atmosphere in the kiln, and the pressure, and thereby produce desired colors on the face bricks. Decided improvements have been effected for each successive burn.

Columbia University Announces New Courses in Fuel Technology

To meet the growing demand for instruction of engineers in fuel technology Columbia University, New York City has added two new extension courses aimed to treat from the chemical engineering standpoint the applications of scientific principles in the production, distribution, and utilization of solid, liquid, and gaseous fuels.

The subject matter is to be introduced mainly by assigned readings in textbooks and in technical periodicals. The classroom periods will be used for discussions of the material in the assigned readings and of problems involving design.

The first course covers the theory of combustion with special reference to solid and gaseous fuels; production (mining methods excluded) of natural and derived solid fuels; carbonization of coal at low and high temperatures; production and purification of gaseous fuels; storage and distribution of city gas; utilization of fuels including temperature measurement, furnaces and fuel appliances, heat balances, and fuel efficiencies; public utilities and their relation to the fuel question.

The second course treats in general of the importance, origin, and occurrence of fuels and in particular of the winning, refining, and marketing of petroleum and its products. It includes discussions of the theories of heat transfer, of condensation, and of cracking of hydrocarbons in their applications to refinery practice; petroleum and natural gas as chemical raw materials; oil shales and other sources of liquid fuels; and the utilization of liquid fuels.

Both courses are given under the direction of Professor J. J. Morgan.

The Capnometer— An Instrument to Measure Smoke

Over a year ago an air pollution investigation was inaugurated by Mellon Institute of Industrial Research, Pittsburgh. Through the cooperation of staff members of the Institute and of the Westinghouse research laboratories, the photo-electric cell has been successfully applied to measuring smoke and other forms of air pollution.

In its present development, the device consists essentially of a source of light with a modulator, a receiver and amplifier properly tuned and an indicator or recorder, carefully calibrated. It is continuous in its operation and neither daylight nor outside sources of artificial light affect its functioning.

At the suggestion of W. A. Hamor, assistant director, Mellon Institute, the new apparatus has been named the *capnometer* (< Greek *Kapnos*, smoke, and *metron*, measure), since its purpose is to measure smoke—*capnometry*.

Thus a new instrument and a new name are provided for the Combustion Engineer.

Gas Industry's Sales Increase

An increase in sales during April in practically every branch of the gas industry was noted by Paul Ryan, chief statistician of the American Gas Association. Reports from companies representing about 90 per cent of the entire manufactured gas division of the industry, indicate that sales during Arpil aggregated 31,943,694,000 cubic feet, an increase of 6.5 per cent over April of last year.

Reports from the larger natural gas companies, representing approximately 70 per cent of the public utility distribution of natural gas, show sales of 35,660,086,000 cubic feet for April, as compared with 34,451,677,000 cubic feet sold by the same companies in April, 1929, an increase of 3.5 per cent in natural gas sales. Were it not that general business and industrial activities in certain sections of the country are still below normal, a still larger increase in natural gas sales would have been shown. This condition is reflected in a decrease of more than 5 per cent in sales of natural gas for industrial purposes during the month. Natural gas sales for domestic and house-heating purposes, however, registered a gain of nearly 10 per cent, while commercial sales, mainly to hotels, restaurants, public buildings, etc., showed a 13 per cent increase.

The number of customers served, continued to show a steady growth during the first four months of 1930. As of April 30, 8,835,930 customers were served by the manufactured gas companies, a gain of about 2 per cent, while those served by the natural gas companies reporting totaled 3,599,554, an increase of 2.2 per cent over April 30 of 1929.

Natural Gas Consumption Gains

A marked increase in the use of natural gas fuel for generating electric power by public utility companies is reported in a recent survey of the natural-gas industry by G. E. Barrett & Co., bankers specializing in natural gas projects. During 1929, the survey states, this "particular field used 112,847,000,000 cubic feet or 46 per cent more than in 1928, compared with 21,000,000,000 cubic feet used in 1919. About one-tenth of the electricity used today is a converted form of natural gas."

There is a strong tendency on the part of manufactured gas companies to mix natural gas with the manufactured product to increase its efficiency and give greater economy according to the survey. It is further reported that, in 1929, about 112,000,000,000 cubic feet of natural gas were bought by manufactured gas companies for this purpose, compared with 77,400,000,000 cubic feet in 1928, an increase of 45 per cent, while the total gas output of these companies increased only about 9 per cent. The survey reveals that nearly one-half of all cities of the country provided with gas mains are supplied with natural gas.

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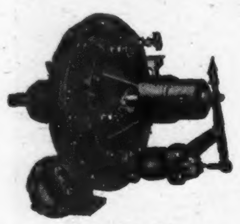

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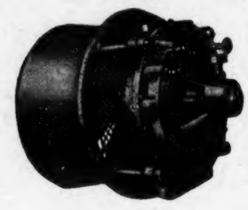

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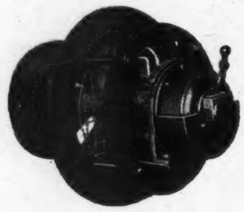

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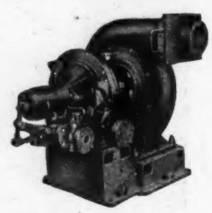

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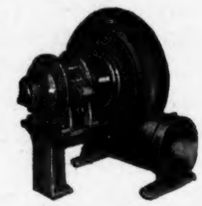

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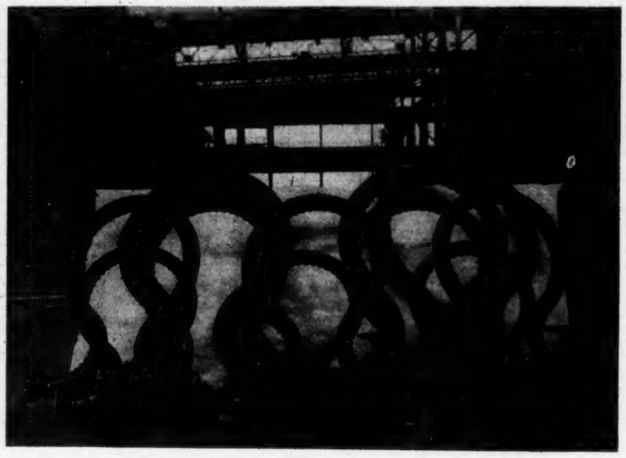

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